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SOCIETY OF MOTION PICTURE ENGINEERS

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SOCIETY OF MOTION PICTURE ENGINEERS

Membership in the Society of Motion Picture Engineers stands for unselfish service to the Industry. Applications for membership are by invitation and endorsement. All checks should be made payable to the Society of Motion Picture Engineers.

All receipts are expended directly to promote the objects of the Society and the interests of its members. There are no salaries or emoluments of any kind.

The following are extracts from the By-Laws:

The objects of the Society are: The advancement in the theory and practice of motion picture engineering and the allied arts and sciences, the standardization of the mechanisms and practices employed therein, and the maintenance of a high professional standing among its members.

An Active Member is one who is actually engaged in designing, developing or manufacturing materials, mechanisms or processes used in this or allied arts, or who is interested directly in the art.

Any person of good character may be a member in any or all classes to which he is eligible.

Prospective members shall be proposed in writing by at least one member in good standing, and may be elected only by the unanimous vote of the Board of Governors.

All applications for membership or transfers in class shall be made on blank forms provided for the purpose, and shall be accompanied by the required fee.

The entrance fee for all members shall be twenty-five dollars ($25.00). The annual dues shall be ten dollars ($10.00), payable in advance before the annual meeting (October) of each year. That is, the total fee for the first year, which includes the entrance fees and first annual dues, is $35.00 for all members.

PRESIDENT'S ADDRESS

Gentlemen:

The organization of our Society had four objects in view, three of which are mentioned in the by-laws because they would never be so completely attained that further progress would be impossible. The fourth object was inferred only, because one day we will have accomplished this object fully.

I refer to that day, greatly to be desired, when our industry will be respected. At this time our industry is known as "the movies," a term of derision, though the term is so expressive that eventually it will be accepted in our language and appear in standard dictionaries, but at present a term of mild contempt, nevertheless.

There is today no other industry at once both so big and so defenceless. The latter accounts for our detractors' distortion of facts.

First, the motion picture industry is openly charged with a deliberate intent to pander to the lowest moral taste; and so we have censorship boards.

Now, if this opprobrium is deserved, steps should be taken to correct this condition. If it is not deserved, an unobtrusive, but persistent campaign to change public opinion should be inaugurated.

Second, it is alleged that our industry is extra hazardous, and so we are denied privileges accorded other industries far more hazardous.

Believing these conditions might be improved I have been working for some months, single-handed, and I have made some progress, arguing on the hypothesis that there are but two causes of film fires, namely, (1) the machine and (2) the operator. Any effort to reduce the fire hazard from either cause is worth while, it seems to me.

One result already achieved is a specification prepared in collaboration with an officer of the National Board of Fire Underwriters for a projector with so high a safety factor that it may be used without a booth, for should this be adopted by the Board of Fire Underwriters it will prove a wonderful boon to educational institutions; to industrial organizations; in rural development, and in hundreds of other avenues of usefulness.

The motion picture does not deserve the bad name for hazard which it now has. I feel that projecting machines can be made which will not cause film fires under any circumstances. Many fire and insurance officials concede that this is possible, but contend that the film is unsafe. But is it? The express companies and parcel-post carry about five hundred tons of it daily, and safely.

I have been claiming for some time that the other element, the concealing booth, is the cause of most film fires, and to authoritatively discover the accuracy of this assumption, I asked the National Fire Prevention Association for a report on the subject. This data was graciously furnished and was afterward made the subject of official report, and this will be found elsewhere in the proceedings of this meeting. Needless to say I was gratified to learn that not a single film fire was recorded as occurring when the exhibition was given without

a concealing booth; and also that more than sixty per cent of the common causes of booth fires were such things as would prevail only where the operator is concealed, that is, smoking, carelessness, a dirty booth, and failure to immediately return the film to its metal container. Smoking alone made up more than fifty per cent of the common causes of film fires.

I think, therefore, that our contention has been substantiated, namely, that a machine can be made which is safe within itself, and that film is not as hazardous as the unusually stringent regulations would seem to indicate. Both of which will greatly enlarge the usefulness of motion pictures in the immense field outside of theatres.

It is suggested, therefore, that, at this meeting, we put into motion two activities, *i. e.*, (1) efforts looking to the approval of a safe machine for use outside of theatres, and (2) a publicity campaign for better regard for our industry by the public generally. The first will come up under the head of new business at this session, doubtless; and as for the latter I suggest that the continuation of such publicity be so directed as will make for a higher regard for our industry, and, so far as practicable, that it be made in the name, and in such a way as will maintain the dignity and unselfish motives, of our Society.

Already much has been accomplished, and each of our meetings is better than the preceding one. A steady continuation of our splendid work will make the Society of Motion Picture Engineers a great power for advancement.

Standardization of Exposure

John W. Allison

Standardization of an industry should begin at the beginning, and as the producers of motion picture film have a standardized product to start with, *i. e.*, the film, the first thing for the producer to standardize is the exposure, and this can only be done by standardizing the conditions under which the film is exposed. Of course, I refer to work in the studio.

Messrs. Hurter & Driffield, of England, whose research work in the photographic field is recognized as standard throughout the world, put great stress on the necessity of securing a technically perfect negative. Let me quote a few words from their little book on "Photo-Chemical Investigations and Methods of Speed Determination":—

> "While we quite realize that the artist will always produce the best *picture*, we contend that the scientist will produce the best *negative*. The photographer, therefore, who combines scientific method with artistic skill is in the best possible position to produce good work.
>
> "The truthful representation of light and shade involves the production of a technically perfect negative, *i. e.*, one in which the opacities of its gradations are proportional to the light reflected by those parts of the original object which they represent. Our investigations show that such a relationship does exist, but only when a plate has received what we term a *correct exposure*.
>
> "While many photographers attach very little importance to accuracy in exposure, and maintain that errors may be readily corrected by suitable modifications in the composition of the developer, we have always strongly insisted that a correct exposure is an essential foundation if we aim to procure a technically perfect negative. It must be clearly understood, however, that, by a correct exposure we do not imply that there is necessarily one exposure, and one only, which will yield a negative answering to our definition. Fortunately, most plates admit of some latitude in this respect.
>
> "Our contention is that the latent image, false in its gradations, cannot, by modifications in the constitutions of the developer, be made to yield a visible image true in its gradations. The practice of photography, by methods of scientific predetermination, imperatively demands a correct exposure as a fundamental condition."

The standardization of the exposure so that at all times every foot of film exposed in the studio will be uniform in density will do away with the necessity of variations of timing on the printer, and eliminate the uncertainty of the finished result, and one can predetermine the screen results when toning or dying is resorted to.

I have been working on an indirect system of studio lighting to standardize the exposure, in which the volume of indirect light is

governed by the cubical area to be lighted, and in addition to which the light effects are secured by the use of a few diffused direct light units. In this way the photographer can exercise his artistic ability with the assurance of a perfectly exposed negative resulting. Of course, studio conditions will have to be somewhat changed from the present methods of working, but the certainty of the results will warrant the expense.

To my mind the use of direct light in the studio is a great mistake. Ninety percent of the time we spend in indirect, or reflected light. Such being the case, why should we not make our photographs under the conditions under which we normally live?

The Eskimo is a specimen of a human being who spends most of his life under direct light. Now who wants to look like an Eskimo?

By careful use of the exposure meter, in outdoor work, the exterior exposures can be standardized to balance with the studio work, so that the same treatment will do for both.

Optical Requirements of Motion Picture Projection Objectives

By ALFRED S. CORY

In the motion picture industry, as in every other modern industry, the trend in mechanical and technical matters is always towards increased efficiency combined with improvement in quality, and on the present occasion I bring to your notice the results of a comparative study of motion picture projection objectives from the standpoint of their defining properties and the efficiency with which they utilize the light source of the motion picture projector.

As the analogy between the production of an image, or picture, in the photographic camera, and the reproduction of an enlarged screen picture by the motion picture projecting machine, is a very close one (*the two processes being in fact merely the inverse of one another*) we are provided with a ready means of studying and comparing the capabilities of projection objectives, by subjecting them to the same considerations that are applied to the investigation of the properties of photographic objectives, but before we proceed there is a difference which should be pointed out between the character of the work which is to be accomplished by the photographic objective and the projection objective respectively.

In the case of the photographic objective the angular field, or field of view, required to be covered is seldom less than 30 degrees, which is considered a very narrow field in photography, but in the case of motion picture projection the field which comes into play is only about 15 degrees in angular extent, (*for an objective of 4″ E. F.*) and is even less in the case of long focus lenses. Were it not for these extremely moderate requirements, as regards the angular extent of the field of view, the effect of the aberrations of the customary projection objective would be much more apparent in the screen reproduction.

On the score of aperture, or intensity, however, the requirements of photographic objectives and projection objectives are identical, for in both cases the greatest aperture is essential which is compatible with freedom from a noticeable amount of aberration in the projected pictures. Thus the bundles of rays transmitted by a projection objective are of large angular section, as in the case of the photographic objective, but the most extreme rays from the film picture to be projected have very slight inclinations to the axis of the objective when compared with the obliquities met with in photography.

As is well known, the images formed by lenses are affected, as regards sharpness or quality of definition, and as regards the accuracy with which they reproduce the projected object, by a series of aberrations, the most representative aberrations, from the viewpoint of the optical constructor being:

(1) Chromatic aberration (*due to the composite nature of white light*).

(2) Axial spherical aberration.

(3) Spherical aberration for points outside the axis.
(4) Astigmatism.
(5) Curvature of the image field (*invariably associated with 4*).
(6) Distortion.

A brief outline of the cause of these various aberrations, their effect on the projected image, and the requirements for their elimination, or correction, will be given, and a comparison between the customary projection objective, and some objectives of improved construction, will be made on the basis of the extent to which the various aberrations have been eliminated in the several types of objective considered.

To save time in reviewing the effects of the several aberrations upon the definition of the projected picture, we will assume in the first place, that any objective which is worthy of investigation has been chromatically corrected for at least two spectral colors, and has also been spherically corrected for rays parallel to the axis, *i. e.*, is so corrected that the axial ray and the edge ray after refraction by the objective cut the axis at the same point, which point of intersection is known as the focal point of the objective in question.

The fact that an objective is spherically corrected for the center of the field does not, however, assure the sharp reproduction, in the image, of portions of the object which are situated outside the axis, because the zones of the objective between the axis and the margin exert their influence on oblique pencils in a manner which is quite fatal to crispness in the image, and this effect is number 3 on the list of aberrations, being known as coma. Spherical aberration of the oblique pencils of rays gives a fuzzy appearance to the image, the reason for this being that the various zones of the objective have not the same magnifying power, due to the unsymmetrical refraction of the rays in the meridian sections of oblique pencils. In first approximation Abbe showed that for the elimination of coma the ratio of the sines of the angles made with the axis by any and every ray proceeding from the axial object point and refracted to its image point must be constant, or in other words

$$\frac{\sin u'}{\sin u} = \text{constant}$$

where u is the angle which the incident ray makes with the axis and u' is the angle which the refracted ray makes with the axis. This ratio must also be equal to the linear magnification. In the case of parallel incident rays the relationship

$$\frac{h}{\sin u'} \text{ must be constant}$$

where h is the height of incidence of the ray considered, measured from the axis. This ratio must be equal to the equivalent focal length of the objective and the difference between the value of $h/\sin u'$ and the equivalent focal length, F, for any zone of a given objective repre-

sents the deviation from the sine condition for that zone of the objective, and if the sine condition is approximately fulfilled in an objective the values of

$$\frac{h}{\sin\ u'} - F$$

for the various zones will be nearly equal to the outstanding spherical aberration for the same zones as compared to the focus of the axial ray. Zonal variations of the equivalent focal length are eliminated over a narrow field, *i. e.*, up to 7 degrees from the axis (*15° field of view*) when the sine condition is fulfilled as a first approximation, but in the case of wider fields a special correction for coma may be necessary, which is, however, outside the scope of the present considerations.

The commercial varieties of projection objective are made along lines similar to those proposed by Petzval in 1840, and the deviations in present day manufacture from the original Petzval Portrait objective are so slight that the projection objectives now generally in use are similar in their characteristics to the original Petzval lens. The Petzval objective has always been celebrated for its critical definition in the center of the field, which compares very favorably with the most modern objectives over a restricted area in the vicinity of the axis.

At a distance of 12 mm. from the axis (*corresponding to one-half the width of a film image*) the deviation from fulfillment of the sine condition commences to assume such proportions, however, that there appears to be room for improvement through the use of some other type of objective wherein the sine law is fulfilled for a greater distance away from the axis, because the edges of the motion picture image are outside of the region over which this important correction is operative in the case of the Petzval objective. By the use of certain types of photographic anastigmats as projection objectives a field much in excess of the diagonal of a film image may be secured which is free from coma, and as these modern types of objectives appear to possess numerous other advantages they will be considered more extensively in the course of my remarks.

A further deterioration in the definition of the projected motion picture image is the result of astigmatism and curvature of field, two associated aberrations which appear as numbers 4 and 5 on our list.

A description of the effects of astigmatism and curvature of field upon the projected image will show the importance of correcting the projection objective for these aberrations, so we will dwell briefly upon the matter, reference being had to Fig. 1.

In the diagram a pencil of light rays, supposed to be of very narrow cross-section, is incident obliquely upon a positive lens. The cause of astigmatism is found in the fact that a different contour of lens surface is presented to sections of the incident oblique pencil which are 90° apart, and the refracting effect of the lens is thus different for different portions of the incident pencil.

The section of the oblique pencil of rays which contains both the axis of the pencil and the axis of the lens is known as a primary or meridian section, and is denoted by **A B** in the diagram, while the sec-

tion at right angles to A B *through the oblique pencil* is known as the secondary or equatorial section C D of the same oblique pencil. Proceeding now to follow the course of the rays after the oblique pencil has been refracted by the lens, we note that the rays of the equatorial section C D come to a focus at I in the form of a line, which radiates from the axis, while the rays of the meridian section A B, come to a focus further back at II as a horizontal line which is at right angles to the radial line at I, or, more strictly, it is tangential with respect to the circular image field. At the position I, therefore, we have vertical, or radial elements of the object in focus and horizontal details blurred beyond recognition, while at II we have horizontal, or tangential, object elements sharply delineated but the vertical elements hopelessly out of focus. Somewhere between I and II is a position of minimum indistinctness which is known as the circle of least confusion, and would represent the best marginal definition attainable with the uncorrected lens.

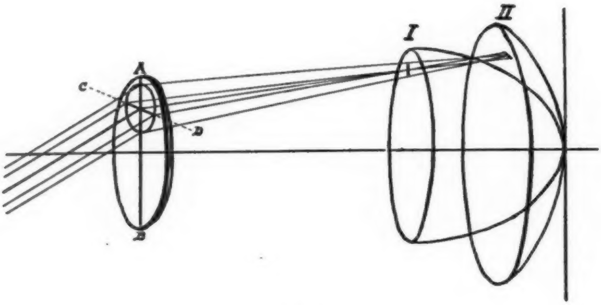


FIG. 1

The converging of oblique pencils to two focal-lines is not the only consequence of oblique refraction, however, for the respective radial and tangential lines are located on two very curved surfaces, as the diagram shows, and these curved image-surfaces only coincide at the axis of the lens. The difference between the curvatures of the I and II astigmatic image-surfaces is known as the astigmatic difference, which increases with increasing angles of obliquity of the incident rays. This deformation of the image-surfaces, *i. e.*, their departure from the flatness of an ideal focal-plane is known as curvature of the image-field, and it is found desirable when correcting an objective for the removal of astigmatism to abolish the astigmatism and the curvature of the field simultaneously.

By suitable design and choice of the glasses, an objective may be made which brings the I and II image-surfaces into contact, whereupon the lens is free from astigmatism and renders a sharp image, but this single anastigmatic image-field may still be a very considerably curved surface. It is therefore the aim of the optical computer to render the field flat and perpendicular to the axis at the theoretical focal-plane simultaneously with the bringing together of the I and II image

surfaces. This is accomplished when the Coddington-Petzval condition is fulfilled, which requires that

$$\sum \frac{1}{r} \Delta \left(\frac{1}{n} \right) = 0$$

i. e., the sum of the products obtained by multiplying the curvature of each refracting surface by the difference of the reciprocals of the refractive indices of the media bounding that surface must be zero. When this equation does not equal zero its value indicates the curvature of the image-field at its vertex, or, in other words, at the axial focal point.

NOTE—*The Coddington-Petzval condition is only operative when the astigmatism has first been abolished, that is when*

$$\sum \Delta \left(\delta \right) = 0$$

i. e., the sum of the differences in the diameters of the circles of confusion (*corresponding to an extra-axial point of the object*) resulting from the refractions at each of the surfaces of the system equals zero.

In the case of some modern photographic objectives the astigmatism and curvature have been eliminated over a very wide field of view, although in anastigmatic corrections, as well as in ordinary spherical corrections, there remain, in the case of most objectives, small outstanding zones where the I and II image-surfaces have not been brought completely into contact, or where the field is not perfectly flat and at right angles to the axis of the objective.

As a concrete instance of the existence of these astigmatic deviations, and departure from strict planeity of the image-field, the Petzval type of projection objective shows a noticeable degree of astigmatism, or curvature of the field, or both, at 5° from the axis (*corresponding to a field of view of 10°*) while at 7° from the axis (*corresponding, roughly, to a 15° field of view*) the astigmatism, or the curvature, or sometimes both, are of quite appreciable extent. To those who have never experimented with lenses from the constructional point of view it will be of interest to state that by separating the front and rear components of a Petzval type objective the flatness of the image-field is improved, but at the same time the I and II image-surfaces tend to separate from one another more and more as the lens components are spaced increasingly farther apart, so that flatness of field is attained at the expense of increased astigmatism when the correction depends solely upon the empirical principle of separation. On the other hand a very close approximation to complete coincidence of the I and II image-surfaces may be brought about by bringing the components of the Petzval objective close together, thus eliminating astigmatism almost entirely, but in this case a very much curved field results, which is equally as objectionable as the presence of astigmatism both to the photographer and the optical projectionist.

As it is therefore to be seen that the Petzval objective possesses neither complete freedom from astigmatism, nor a perfectly flat field of sufficient angular extent to permit of perfect definition over the entire extent of the projected motion picture image, it appears that in order to achieve the utmost in sharpness in cinematographic projection some of the modern types of highly corrected objectives could be utilized to advantage in this class of work. Projection objectives of the photographic anastigmat type have been used n England and on the continent for some years past with great success, and I need not therefore apologize for directing the attention of the Society, and the industry at large, to the improved results which may be secured by the use of projection objectives of modern design.

The number of different types of highly corrected or so-called anastigmat photographic objectives now on the market is very large, but only a few types are eminently suitable for projection purposes, the principal requirements of a projection objective, in addition to the abolition of the previously mentioned aberrations, being:

(1) Large effective aperture.
(2) Minimum of (*glass-air*) reflecting surfaces.
(3) Minimum of cemented surfaces.
(4) Compactness of construction, *i. e.*, short distance between the front and rear components.

When these requirements and also the corrections for flatness of field and freedom from astigmatism are taken into consideration, the selection narrows down considerably, and of the many modern photographic objectives available I direct your attention to only two specific types, these being the Cooke objective series II *f* 4.5, the Zeiss I C Tessar *f* 3.5.

For the purposes of cinematographic projection both the Cooke Series II and the Zeiss I C Tessar can be made with effective apertures of *f* 4.5 or even *f* 3.5, and beyond an effective aperture of *f* 3.5 it seems extremely inadvisable to go, because with further increase in the effective aperture the aberrations inherent in all objectives can no longer be suppressed to the degree at which they are invisible in the projected results.

The influence of residual aberration upon the screen images produced by objectives of extremely large effective apertures may be readily demonstrated by projecting a test slide, or film, containing printing or any other fine contrasty pattern. It will then be found that the blackness of the letters, or pattern, is much more pronounced when projection is accomplished with an objective of moderate aperture than is the case when one of extreme aperture is employed, because the residual comatic and astigmatic errors which are inseparable from objectives of large aperture tend to gray the projected image, thus robbing it of a certain degree of snappiness or proper contrast.

The Cooke lens has six glass-air surfaces, as has also the Tessar, both being identical with the Petzval objective in this respect. In view of the light loss by reflection at glass-air surfaces an objective

with only four open surfaces would be desirable for projection purposes, but the production of such an objective of sufficiently large aperture does not seem compatible with the corrections required, although some of the objectives designed by Hugh L. Aldis of Birmingham, England, are suggestive efforts along this line.

In respect of cemented surfaces, the Cooke lens has none, being ideal in this respect for projection with high power illuminants which generate considerable heat; the Tessar has one cemented surface which would doubtless hold up well as no trouble is ever experienced with the cemented surface in the Petzval type objectives now commonly in use. The Cooke and the Tessar objectives are both of compact construction and are therefore superior in this respect to the Petzval objective, an advantage which will be again referred to.

The corrections for coma, astigmatism and curvature of field are carried out to a high degree in these two modern types of objectives; there being no noticeable departure from the sine condition, and the field being almost perfectly flat and free from any noticeable trace of astigmatism for upwards of 10° away from the axis, thus allowing the projection of a sharp stigmatic image of 20° or more in angular extent.

Distortion, the seventh aberration on our list, has been deferred until the last because under the conditions generally met with at present wherever motion pictures are projected, the elimination of distortion would appear to be an almost needless refinement in a projection objective, although, of course, this correction should be carried out to the utmost extent possible in a large aperture objective, and is carried out by all reputable opticians.

Distortion in a photographic or a projection objective may be briefly described as an increasing or a decreasing scale of reproduction from the center to the edges of the images produced by objectives of either simple or compound type, and it results from the refractive effect on rays incident at increasing angles with respect to the axis being such as to cause the angles made with the axis by the chief-rays after refraction to differ from the angles made by the same rays, with respect to the axis, before refraction.

(NOTE—*A chief-ray is the representative ray of a pencil; it is the ray which passes through the center of the diaphragm of an objective and therefore through the center of the entrance-and exit-pupils.*)

In order that an objective may be free from distortion, and yield an orthoscopic, or rectilinear, representation of the object projected, Airy's condition must be fulfilled, which requires that the ratio of the tangents of the angles made with the axis by corresponding chief-rays on the object side and on the image side of the objective must be constant, or

$$\frac{y}{y'} = \frac{a \tan w}{a' \tan w'} = N$$

where y and y' represent the size of the object and the image respectively; a and a' are the distances of the entrance- and exit-pupils from the plane focussed for (*the film image in motion picture projection*) and the image plane (*or lantern screen*); w and w' are the angles made with

the axis by corresponding chief-rays on the object side and the image side of the objective, and N is the reduction factor.

The "tangent condition," as it is generally known, is precisely fulfilled *in the case of symmetrical objectives*, for one pair of conjugate positions of the object and image, *i. e.*, in the case of unit magnification, and freedom from distortion may be realized for certain other positions of the object by also correcting a symmetrical objective spherically with respect to the position of the diaphragm and its images—the entrance- and exit-pupils (*Bow-Sutton condition.*)

Orthoscopy is not completely realized for any distance of the object by unsymmetrical objectives, however, and with respect to correction for distortion most of the modern anastigmatic objectives show about the same amount of positive distortion as the Petzval type projection objective. This is not a matter of such moment in every-day motion picture projection as it is in photographic reproduction work, for in less than one theatre out of every hundred is the center of the screen co-axial with the projector optical system, or the entire screen perfectly perpendicular to the axis of projection. Inasmuch as operators, theatre managers and architects have failed in the majority of cases to provide for an orthoscopic representation on the projection screen, it can be claimed that the distortion errors due to conditions prevailing in the majority of theatres far transcend the amount of distortion to be found in the images produced by any of the modern types of objectives, when they are used for projecting upon a screen placed truly perpendicular to the axis of projection.

(NOTE—*For convenience I have created the expression "axis of projection" which is defined as the prolongation of the axis of the projector optical system* (*assumed to be in perfect alignment*) *as a straight line to the projection screen. I suggest that this definition be adopted by the Society and included in the Society's list of Motion Picture nomenclature*).

As all of the modern anastigmatic objectives having a large aperture are of unsymmetrical construction, they exhibit about the same amount of distortion as to Petzval objective at angles up to 10° from the axis, but there is one notable exception to this statement—the objective in question being the I C Zeiss Tessar of *f* 3.5 aperture ratio. In this objective, which has previously been recommended as eminently suitable for projecting purposes, distortion has been reduced to an almost negligible quantity at 10° away from the axis, which is quite remarkable considering the large aperture. I have not been able to examine one of the recent Cooke anastigmatic projection objectives which are said to work at *f* 2. and I cannot therefore report upon it with respect to distortion, but the Cooke objectives of smaller effective aperture are very well freed from distortion, thus indicating the possibilities of securing a good correction in this respect for the Cooke objectives of larger aperture.

A final advantage which can be claimed for the modern types of photographic objectives, when used in motion picture projection, is their compact construction, which permits a very efficient utilization of the available light source.

An elementary investigation will show that in the case of the Petzval type of projection objective generally in use, a considerable amount of the light proceeding from the margins of the machine aperture (*or film picture*) is intercepted within the mounting or tube of the objective, and can not therefore reach the projection screen. By the use, however, of the types of objectives recommended in this paper, a considerable amount of light which fails to reach the projection screen, due to the vignetting action of the customary objective, may be fully availed of, because anastigmatic objectives, such as those used in photography, are characterized by a much shorter distance between their front and rear components than is the case with the Petzval objective. In virtue of this fact, a modern form of objective of compact construction can transmit as much light as a larger aperture objective of the same focal length but with greater separation between the components, and when we consider that the visible effects of aberration increase with increase in the relative aperture, it is clear that improvement in motion picture screen delineations must be reached through the compact and efficiently corrected modern anastigmat objectives of similar type to those recommended.

My thanks are due to Dr. Hermann Kellner for having kindly gone over this paper prior to its presentation before the Society, and also for some demonstrations relating to the subject made at the Bausch & Lomb Optical Works.

Artificial Light in the Motion Picture Studio

By Max Mayer

When we turn back to the early pages of motion picture history, we come to the time when our pioneer producers began to look upon picture-making as an everyday and allday task, rather than an occasional diversion.

It was then that the pranks of old Sol began to be felt more keenly than when it was practical to wait for the clouds to roll by.

Confronted by a rapidly growing demand, the producer readily saw two alternatives; the land of eternal sunshine or artificial light, so he promptly reached out for both.

Artificial light was being extensively used both for still photography and in the Graphic Arts, and fairly suitable units were therefore available for cinematography.

At the time the main aim was to get lamps enough to light the sets, and somehow they never seemed able to get quite enough, no matter how many were used.

This condition prevailed, until the more recently developed tendency, to produce pleasing and natural light effects, superseded the earlier method of flooding the scenes with light from every available point.

Thus the lights were used virtually to produce shadows and contrasts, and far better results were attained with less light; in fact, many effects difficult and impracticable to obtain by sunlight are more readily achieved in a darkened studio with suitable electrical equipment.

This subject as a whole is wide in scope, and the writer dares herein to attempt nothing more than a superficial discussion thereof.

To this end three general classifications will aid in dealing with the topic:

(1) The nature of the light sources;

(2) The manner of their application;

(3) The manner of installation of equipment.

Under the first heading, consideration should be given to the color composition of the light, the degree of concentration of the light source itself, the nature and value of reflectors and auxiliary reflecting surfaces—and the nature and value of diffusing screens.

1 Color Composition of Light

The color sensitiveness of the photographic emulsion, of course, determines the usefulness of the spectrum range of the light source.

The modern film used in the motion picture camera is sensitive over a considerable portion of the sun spectrum and consequently sunlight will record on the film more speedily and correctly than a light source in which one or more colors to which the emulsion is sensitive, are absent or weak.

Artificial light sources which do not cover the full sensitive range of the emulsion can not give maximum results, unless used in conjunction with other light sources which supply that deficiency.

The mercury vapor lamp, though completely lacking in some colors, is nevertheless a valuable unit for this work, owing to its wonderful light diffusion and is very extensively used in conjunction with powerful arc lamps employing "white flame" carbons.

There is a great deal of valuable information to be gathered on photographic color values, and it is to be hoped that the S. M. P. E. may be favored at an early date with a paper on this topic by some of the many brilliant men of the Eastman laboratories.

CONCENTRATION OF LIGHT SOURCE

If a light source be considered as a point, the light would emanate therefrom equally in all directions, and the rays would all form diverging angles. Such a point of light would be the extreme concentrated light source. Consider now a plane surface—a square, for example, formed by minute light sources, whose collective intensity is equal to an assumed intensity of the aforementioned concentrated light source.

Such a luminous surface might be considered an ideal diffused light source. At a given distance, this diffused light source, as compared with the concentrated light source, would evenly illuminate a greater area at a proportionately lesser intensity.

In the language of the studio, the light from the luminous surface would not carry so far as the concentrated light, but would be more scattered or diffused, producing an effect often very much desired in photography.

If the light, from a concentrated light source, such as a flame arc, for example, is passed through a piece of roughed glass or similar medium, a diffusing or scattering effect may be obtained, involving, of course, a loss proportionate to the absorption of the medium. Thus it is practicable to obtain most any degree of diffusion from a concentrated light source; but the scattered light from a luminous surface cannot be concentrated.

Another form of concentrated light, now extensively used as an auxiliary, is the projected beam or spot light. This is usually in the form of a high-powered hand-feed arc, (70 to 100 amp. and often more) with a single plano-convex condenser. The principal fault with this form of unit is its low efficiency, probably mostly due to the filtering effect of the thick condenser glass. However, the striking effects obtained by this means will easily offset this inefficiency.

It might be interesting and instructive to note the effect obtainable through a condenser lens of quartz as compared with the ordinary glass condenser.

REFLECTORS AND REFLECTING SURFACES

The uses of reflectors on various types of lamps are to re-direct the rays (which would otherwise go in useless directions) toward the object to be illuminated, and further to obtain by their use various degrees of concentration, according to the shape of the reflectors. While

surface mirrors would probably represent the ideal reflecting surface, their use would hardly be practicable owing to the difficulty of keeping large numbers of them clean under the studio conditions.

Either a mat white surface of slightly bluish tint or a mat aluminum surface are found quite satisfactory, particularly for the flame arcs, as the white ash deposit from the carbons does not materially alter the reflective value of the surface; thereby keeping the light source practically as constant as the lamp itself. With mirror-surfaced reflectors, this ash deposit would gradually decrease the light strength, and cleaning would suddenly restore it to full brilliancy. It is plain that this would be a disturbing factor to the camera man.

The value of reflecting panels has long been recognized by portrait photographers. Cinematographers also use them when working with sunlight; but they have been slow to adopt them in conjunction with artificial light. These auxiliary reflectors are, however, none the less valuable for this purpose. Mat white or aluminum painted surfaces have been the customary practice, but a much more effective reflecting surface may be made by stretching white oil cloth on a frame, treating the smooth surface with sizing and coating it with leaf aluminum, in a manner similar to that employed in show-window lettering. Such reflectors will do wonders in bringing out detail in shadows and in toning down hard contrasts, and will actually reduce the number of lamps required.

DIFFUSING SCREENS

Much experimenting has been done with different materials for diffusing the light and unfortunately the ones which absorb the least light are also least capable of resisting the hard usage in the studio. Very thin glass roughed, finely ribbed, or of otherwise irregular surface, while highly efficient, is out of the question owing to its fragility. Draughtsman's tracing linen is a good and fairly efficient diffuser, but must be kept at a considerable distance from the heat of the arcs to prevent burning or scorching. As this increase in distance from the light source increases the degree of diffusion and necessitates a larger diffusing area, this material is only practicable where extreme diffusion is desired, and therefore, for contrasty effects it is better to use a smaller surface closer to the light source. Strips of glass, about one-eighth inch in thickness, roughed, ribbed or prismatic, give fair results, and one form of diffuser made of woven spun glass mounted in frames does quite as well and overcomes the mechanical weakness of the fragile glass strips.

2 Arrangement of Light Sources

Almost everyone directly connected with the art and technique of motion picture production has some pet ideas of his own on lighting and many who exploit their ideas in their daily work are getting commendable and pleasing effects; some as the result of forethought in arranging the light, and others by mere accident.

However, the arrangement of the lights and reflectors is as much a matter of art as of science, and it is futile to attempt to make fixed rules along these lines. In fact, such a step would meet with just re-

sentment; for many of the beautiful light effects we see on the screen are the result of unique and original ideas of artistic minds.

In photographing the modern film play, no fixed set of light arrangement is practical, as the lights must be placed for each scene to suit the effect desired.

For the general illumination of a scene, the aim should be to attain inconspicuous soft lighting, showing the entire scene and figures therein well modelled and in good detail. In this case, well diffused light and plenty of it is necessary, for if the lamps be placed close to the camera line, the difference in intensity from the light to the opposite side of the set would be extreme, while if the lamps are placed at considerable distance from the line this difference in intensity between opposite sides of the set would be greatly diminished, but the amount of light required would be proportionately greater. With sunlight this disturbing condition does not enter, for with the light source ninety odd millions of miles away, the difference in distance from the sun between opposite sides of the set would make a ridiculously trifling computation. But in the above condition, the intensity diminishing by inverse squares of the distance must be considered, and practice shows that the lamps should be kept away from the camera line by at least one-quarter the distance across the set at that point. However, this is seldom carried out and the camera man is generally blamed for unsatisfactory results, while the real fault lies in the fact that sets are usually so crowded together in the studios, that there is no room left for lamps except close to the camera line. To offset this condition, an excessive amount of top light is then crowded over to the dark side of the set, and while this may help in a way, the effect obtained is unnatural and seldom pleasing.

On the whole it is best to confine general lighting to small sets or to avoid it altogether on interiors. If we study the sunlight illumination of the average room, we find that we must resort to effects in order to simulate the natural conditions and shadows.

Back lighting is a splendid way of obtaining pleasing and natural results. This is effected by placing the lights well back and directing them toward, but not at the camera, masking the direct rays at the lamps and preferably using a shielding tube with perfectly dull black interior, over the lens barrel, to prevent halation.

Thus the figures and objects in the set will be silhouetted and by the proper front arrangement of reflecting surfaces and well diffused lights at a fair distance, the features and details may be perfectly modelled in shadow, with pleasing highlight relief effected by the rear lights. Of course, good judgment and practice are essential to carry this out effectively.

This arrangement adapts itself better for an added light effect from a window, lamp, fireplace, or the like, than a general illumination, as the figures being detailed in shadow will light up readily by contrast when they enter within the range of the added light; while in a set fully lighted, such an added effect requires an extremely powerful light source to further illuminate the already well-lighted features, and the effect is usually spoiled by the bleaching out of detail.

Back light may be effected either by top lamps or floor stands or by both. When top light is used, the lamps are best fitted with diagonal reflectors and hung near the back of the set. Care must be used to hide the shadow line cast by the rear of reflector. The lamps should be so hung that this shadow line comes just at junction of floor and rear wall. In small sets an aluminum reflecting panel suspended in front of camera just clear of the lens angle and another on the floor in front of the camera, both carefully set at proper angles, will supply sufficient front light to outline features and other details in shadow, and a diffused floor light on one side, some distance back of camera, will mould these details most pleasingly.

Such an arrangement, used effectively in one of the studios, consisted of six double arc top lights, one 8 tube mercury vapor bank, a six- by eight-foot hanging reflector, and a four- by eight-foot floor reflector.

This outfit, with no other light was used repeatedly in sets of twenty to twenty-five foot depth with splendid results.

This is just one illustration to show how a pleasing effect may be obtained with a small number of lights.

An almost endless variety of light arrangement could be described here; but that would stretch this already lengthy paper into a probably wearisome volume.

3 Installation of Equipment

First of all let us deal with the manner of installing the overhead lights, as this seems to be a source of worry to everyone equipping an artificially lighted studio.

An overhead carriage or trolley system which facilitates the free and easy movement of the individual lamps or banks, both longitudinally and transversally through the studio, and which provides for the convenient raising and lowering of the lamps; that is the problem usually handed to the architect, or contractor.

After ascertaining the weight of the lamps, the weight of the structure required to move and support them grouped in most any position over an area—usually of 5,000 sq. ft. or more—he finds this a weighty problem in more than one sense; often requiring reinforcement of the building structure to provide for the added weight.

Suitable means must also be provided for carrying the current to the lamps in all positions and when the installation is to be made in a glass studio, it must not obstruct the sunlight nor cast shadows.

When it comes to the reckoning, a system meeting all these requirements will cost a very substantial sum and should be planned by a skilled structural engineer, guided by someone well versed in the requirements of the studio.

In one of the modern studios in the east, the lamps are hung from four independent transverse carriages, each movable longitudinally through the studio. Each carriage is provided with a platform, easily reached from a fixed platform with stairway on one side wall of studio running the entire length. From these platforms the electrician has

access to the lamps, electrical connections and raising and lowering devices. The individual lamps are hung in tracks on these transverse carriages and are thus movable to any position across the width of the studio. Each lamp takes its current through contact shoes from properly protected bare copper feeders strung along the carriages. These feeders on the movable carriages pick up the current through larger contact shoes from a set of stationary bare copper mains strung along the side wall and connecting with the switchboard. The top lights are thus all controlled from one switch.

When a light effect is called for, requiring one or a number of top lights, controlled independent of the rest; provision is made for this in the following manner:

Each lamp is connected to its respective contact shoes through a separable plug with a short piece of flexible cable. In the center of the studio, throughout its length and above the transverse carriages, there is an auxiliary feeder run in conduit, from which are hung at intervals, pendant cables terminating in plugs which fit the plugs attached to the lamps. Thus, any of the carriages may be moved to a desired position, one or more lamps thereon disconnected from the trolley feeder and plugged through the nearest available pendant plugs to the auxiliary feeder which is under separate switch control on the board.

This equipment has proven quite satisfactory, but is cited here merely as an example and not for any superiority over numerous others now in use.

In the dark studio, where sunlight is never available to the camera, it is practicable to dispense with the carriage system by lining or studding the ceiling with lights properly spaced and wired for individual control, so that wherever a set may be placed on the floor, top light is provided by simply switching on the desired lamps. Provision should however be made for raising and lowering the lamps individually, to meet the various conditions.

FLOOR LAMPS

It is hardly apropriate to suggest here, either the kind or quantity of lamps required for any assumed condition, but it is important that all floor lamps be sturdy in construction and light enough in weight to be readily portable. They should be fitted with easy running swivelled rollers of large diameter so that they will readily ride over floor obstables.

The lamps are continuously moved from place to place and ease of handling is very much desired.

Stage cables of 25 ft. length or more, are usually attached to the lamps and dragged about with them. It seems a good suggestion to fit each cable with a separable plug close to the lamp, so that the lamps and cables may be separately moved and quickly reconnected.

DISTRIBUTION OF CURRENT TO FLOOR LAMPS

A simple, safe and flexible arrangement of current distribution, devised by the writer several years ago, is described as follows:

Along both side walls of studio a series of plugging boxes is arranged. Each box consists of a 3-wire 100 ampere (per side) plugging pocket, fed by rigidly installed wires from the switchboard. The boxes should not be more than fifteen to twenty feet apart and about four feet above floor. The pocket openings should be downward. This will prevent their being used for ash trays or storage receptacles.

To each of these pockets is fitted a 3-wire plug attached to a 3-wire stage cable of equal capacity, 20 to 30 feet in length. Each of these cables terminates in a portable spider or plugging box having four 2-wire pockets each of 50 ampere capacity.

The plugs fitting these pockets are attached to the lamps by stage cables of suitable length, usually about 25 ft. In this way each wall pocket would supply four lamps of 50 amperes or less, with a large radius of movement for the lamps.

The switchboard is fitted in addition to the top light switches, with one switch for each plugging pocket, each switch being triple-pole, double throw, with the blades connecting to the plugging pocket. One throw of each switch is connected to a set of bus bars fed through a master switch, the other throw of each switch is connected to a separate set of bus bars, fed either through another master switch or direct from the service.

This enables the electrician to set his switches and lamps so that upon signal he can turn on or off a portion of the lights in a set without disturbing the rest; so that a light change can be played in a scene. In the old days this was usually done by holding the action, stopping the camera until the light change was made and then resuming action.

Before concluding, I want to dwell upon the use of alternating current in the studio.

In the third report of the Society proceedings, a reference is made (Paragraph 6 Report of the Committee on Electrical Devices) to the use of alternating current in the projection arc. The objections cited apply here with only this difference, that in projection there seems no real remedy except converting or rectifying to direct current, while in the studio the remedy is simple on account of the plurality of the light sources. All that is needed, to overcome the phase flicker, is a two phase installation with the lamps properly distributed and balanced on the phases.

A word of caution here to the camera man may save him many feet of retakes.

The exposure variations resulting from phase flicker become particularly pronounced on close up, dissolves and fades. This is due to the variations in the exposure period as the shutter opening in the camera is varied, and as close ups are often made with a single lamp, a flicker results, much more pronounced than that in alternating current projection, where at least the shutter value is constant.

To obviate this, never use a single lamp on alternating current, but always arrange the lamps in pairs connected on opposite phases; the results will surely justify your taking the trouble to see that this suggestion is carried out.

In conclusion, I want to say a word in behalf of the man behind the camera. This subject intimately concerns him; for he is the one who assumes almost all of the responsibility of the lighting. If he is to carry the blame for failures he should also have the exclusive say as to the arrangement of the lights.

Let the camera man make himself thoroughly conversant with lighting and the physical characteristics thereof which aid or disturb the results he seeks to attain, so that the director may be justified in entrusting to him this important phase of the work.

Thus, let Science wait on Art, and good judgment on both.

Condensers

By C. Francis Jenkins

In optical projection, the lantern slide, or the single frame of the motion picture film, is simply a stencil to let directed light therethrough to a receiving screen upon which the enlarged stencil is imaged. This stencil may be opaque with transparent portions, in definite arrangement, as in titles, or it may also contain half tones as in pictures. If light filtered by this stencil were projected from a point source, a projection lens would be unnecessary.

Sharpness of image on the screen depends, therefore, on those rays of light which meet most nearly in a point at or near the shutter position, and in the exact axis of the projection system. All other rays tend to blur the image on the screen though adding to the illumination.

For proof of the first proposition one has but to shift the position of the light source considerably to one side of the axis of projection, while still keeping the aperture fully illuminated, a position which gets no picture at all on the screen; and in proof of the second proposition, to observe that a light source of large area will not, even with the best lens, put as sharp a motion picture on the screen as a point source.

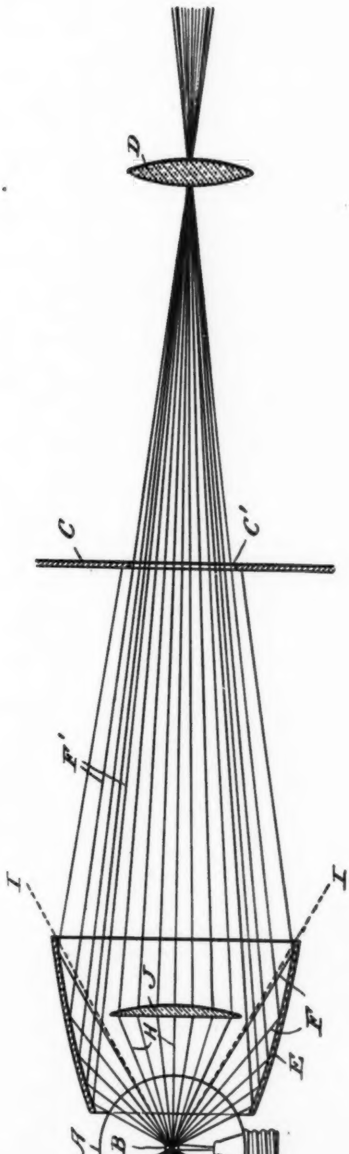
If one had a large stencil to work with, as a lantern slide, a fairly good screen picture could be had with a rather large light source, but as the motion picture frame has less than one-eighth the area of the slide, the most concentrated and intense source of light is required and the highest possible corrected lens.

Given, therefore, a well-corrected lens which will make a picture in spite of defects in the light, further improvement in the system must be in an effort to gather the greatest amount of light and direct it through the stencil of the frame, in the most right lines to a common point, and with the least possible loss.

Designers of early motion picture projectors had the misfortune to begin by using the two thick, light-wasteful, glass condensers employed in magic lanterns. In the lantern the condensers must have a diameter greater than the diagonal of the slide, hence the selection of the 4½-inch diameter in lanterns.

But as the diagonal of the motion picture frame is less than 1¼ inches, a thin, 2-inch condenser would have been quite ample, and we would have avoided the great light loss in the use of 4½-inch condensers, and which has been variously estimated by different authorities to be 75 to 80 percent. Which simply means that if we could effectively employ it, 10 amperes of electric current would do our work where 40 amperes is now required.

Any conservation of light lost between the source and the aperture frame is, therefore, well worth our best efforts, and to determine how we shall proceed, we should analyze the losses and seek the sources. Certainly one of the most glaring is the light reflection and absorption loss and chromatic fringing of the glass of the present system of condensers.



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The obvious method would be to avoid the light absorption loss by using only thin lenses, and to usefully employ light now lost by reflection. Not only would thin lenses avoid absorption loss, but also the prismatic fringes at the blunt-angled edge of the lens.

Keeping well in mind the single fundamental requirement laid down initially, namely, that all rays from the light source should meet at a common point, we find that the most divergent rays, plus those lost by prismatic refraction, can readily be reflected, while those of smaller angle with the axial ray are easily concentrated by a small, thin lens, the total forming an almost ideal cone illuminating the aperture stencil of the frame, and with surprising and gratifying conservation of light.

I think few of us have ever considered the loss resulting from the differences in areas of the rectangular aperture and the circular light spot thereon. The light spot on the aperture plate is often 3 inches in diameter, more frequently 2½ inches, and never less than 2 inches in diameter, including in each case the color fringe. The areas of these spots are 6.75, 4.65 and 3 square inches; and because the area of the aperture is but three-fourths of a square inch, the actual light loss from this cause is 89, 84 and 75 per cent respectively. In other words, we waste from three to six times as much light as we usefully employ. This is not a very creditable showing.

Immense advantages would accrue from any considerable saving of this loss, and while I do not say that this is attainable, neither will I say that it is impossible, for my observation has been that the man who says a thing can't be done has his heels tread upon by the man who does it.

Believing that improvement is worth striving for, my own plan for attacking the problem of light conservation in motion picture projecting machines has been along the lines of eliminating the reflection, chromatic and absorption losses.

A considerable part of the absorption loss is avoided by using a single, thin lens; the chromatic loss by avoiding the prismatic edge of the usual blunt-edged condenser lenses, and reflecting this as white light toward the aperture together with the usual lens reflection loss.

The sketch herewith illustrates how this may be attained, though it may not be the best possible means that can be devised.

The lens converges those rays of light which would be lost in the angle bounded by the dotted lines; the light which would be lost rearwardly is reflected into effective position by the spherical mirror, and all others are directed in the right channels by a single reflection. The whole of the spot is white light and can, therefore, be much more concentrated because there is no colored fringe.

As a general observation I might add that considerable confusion seems to exist regarding the optical system of the motion picture machine, whereas it is not at all complex, consisting as it does of two distinct elements, a reversed camera, and a concentrating illuminating system, and which combined are scarcely less simple than either alone. The first motion picture machine, both my own in 1892-94 and Prof. Lumiere's, of France, practically coincident, were combination camera-projectors, the camera part remaining integral, with a lighting system added thereto when projection was desired.

The Portable Projector; Its Present Status and Needs

By Alexander F. Victor

Those of you who ventured into the new and untried, in the days when the motion picture was an undeveloped possibility, may recall that the first projectors were readily and easily portable. At that early stage of the industry, motion picture projectors were made as attachments to such types of optical lanterns as were then in use.

Film reels were rarely over fifty feet in length; and the usual method of manipulating was to run them through into a box, to be re-wound after the entertainment.

A later innovation was to run them in an endless fashion over a series of spools, lengthening the projection until the audience tired of the film episode.

Never-to-be-forgotten classics were "The May Irwin Kiss," and "The Watermelon Contest." "The Baths of Milano," a Lumiere product, added a full measure of enjoyment to many an evening's entertainment.

I do not know who first realized and expressed the magic possibilities of visualized story-telling. The first reaching-out in this direction that I personally saw, was the "Spanish Bull Fight." This subject was taken and shown by the Electragraph, a projector employing a film somewhat larger than at present used.

The next was the Corbett-Fitzsimmons fight at Carson City. I do not recall the exact footage of these films; but at that time they seemed very impressive.

A little later, an eager explorer reached out and placed a new milestone in the land of the motion picture industry, in the shape of a film dramatic production. Heretofore the "movie" had been a novelty without a permanent field and following. With the advent of the story, the motion picture became an essential part of the people's entertainment.

With the evolution from the short-story to the novelette, and thence to the complete novel—the film length increased amazingly.

The small apparatus of twenty-five years ago naturally proved inadequate to properly handle and project film reels, measuring ten inches and more in diameter. The many mechanical requirements necessary to a creditable performance all conspired to make the portable projector an impossibility. The arc lamp and it's housing; the take-up mechanism, and the resistance element, added weight and subtracted portability.

In spite of these handicaps, the inventor has consistently striven to keep pace with the ever-increasing demands upon his ingenuity.

At this moment, it would seem that the limit in film length had been attained. The film width and reel length have been established by this Society.

Aided by the very able Lamp Engineers—who have produced a wonderfully efficient type of incandescent lamp—the designers of portable projectors have been enabled to produce a machine which successfully handles film reels of one thousand foot length. A projector which delivers a satisfactory ten or twelve foot image, of standard illumination, is extremely compact, easily transported and weighs twenty-five pounds or less.

Motion pictures whenever and wherever you want them are an accomplished fact. Wherever the ordinary illuminating voltage is obtainable—flickerless, brilliant motion pictures are possible.

The portable projector is the logical successor to the optical lantern. It does not enter into competition with its larger prototype—the professional projector; but in the home, in the class-room, in the church and in the equipment of many salesmen, it fills an individual need in a most gratifying manner.

However, in spite of its more than worthy performance and its own most creditable record—the portable projector finds itself in a class of ethical outlaws, due to the company it keeps. No projector, no matter how conscientiously constructed, can take the "flam" out of inflammable film. The professional projector accomplishes the operation by means of the fire-proof booth.

The portable projector becomes equally safe with the addition of the same booth—and accordingly loses its portability. No user could consistently arrive at the place of entertainment, carrying in one hand a truly portable projector, weighing about twenty-five pounds; but in the other hand, a fire-proof booth, weighing five hundred and fifty pounds.

Small wonder that a number of manufacturers, in their eagerness to meet the uncompromising public demand, are supplying portable projectors disguised as sample cases, lunch boxes and violin cases. What cannot be done with safety, according to official requirements, is always accomplished by stealth—with the same lack of safety.

Personally, I do not believe the portable projector to be unduly hazardous, when used in offices or factories—even though inflammable film is used. *But*, when such machines are used, employing inflammable film without booth, in schools and churches—where the apparatus is frequently stationed in the center of a crowded room—then the risk is unwarrantable; unless the operator is skilled and cool-headed.

The amateur, with his indiscriminate use of the portable projector, is a menace to public safety and the good repute of the industry.

There is but one remedy for the present intolerable condition. So long as the market exists—portable projectors will be supplied. Since the uses for which portable projectors are intended, preclude the use of booths—they will be used without.

Since the film employed is the fundamental fault—corrective measures must be applied in that direction. Hence, the non-inflammable film.

This is not a new need; much has been said, but little has been done to alleviate conditions.

Except in one notable instance, manufacturers of portable projectors have listened to the siren song of the argument that only projectors using the standard films would be accepted—owing to the tremendous list of available subjects.

This impressive supply of film has been greatly over-valued. Out of the thousands of film subjects available—comparatively few are adaptable to the needs of the portable projector, whose users require principally Educational and Religious subjects.

I venture to estimate that the existing total of such films will not exceed five hundred, and these so scattered as to make it impossible to secure more than a small percentage of them.

The logical thing to do—it seems to me—is not to meet the obvious public demand, which results in an unhealthy condition; but to furnish the public with a product which meets its needs and creates a sound basis for the industry. Since standardization has produced a large library of inflammable film, why not create by the same means a library of non-inflammable film of suitable subjects and equal volume?

If all manufacturers of portable projectors were to combine and adopt a new standard for such machines, it would be but a short time before an enterprising industry would supply an adequate library of film. Since the number of existing film subjects, suitable to portable projectors, is so limited, it would seem quite practicable to arrange to have them reproduced on non-inflammable stock.

The most apparent obstacle to this plan is this: If a new standard is established by this Society and accepted by manufacturers of portable projectors—who is to make the film?

I would again ask those of you who were with the industry at its beginning, to recall the period when there were but three sources from which to obtain film; although there were at least twenty-five different projectors clamoring for recognition.

I, therefore, feel justified in my belief that the adoption of a standardized, non-inflammable film, will be met with a supply of such film.

Create a demand, and invariably the supply comes to hand.

It may be necessary at first for the manufacturers of portable projectors themselves to make and supply a limited number of reels. Each one doing his bit, the impetus is given and the movement is well under way.

I believe the Underwriters' Code, as it is now drawn, to be very just. I do not believe that non-inflammable film of standard width and perforation (even though it carried a definite label) would sufficiently safeguard the public. Many unscrupulous exhibitors would use the wrong kind, and with everyone unconscious of danger, the risk would be doubled.

There is, in my estimation, the greatest need for immediate action in this most undesirable state of affairs.

I respectfully submit a recommendation to this Society, that the following three subjects be taken up for immediate discussion and acted upon:

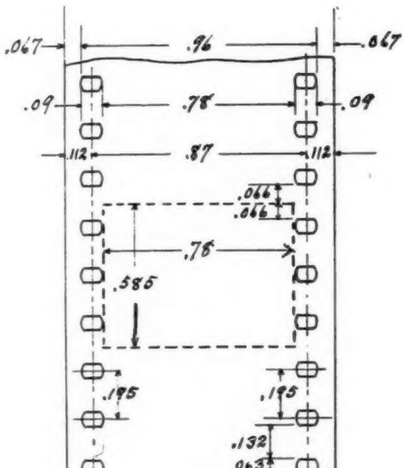
(1) That the present Underwriters' ruling, regarding the use of non-inflammable film be approved by this Society.

(2) That a universal standard be adopted for approved non-inflammable film; so that manufacturers desiring to make and sell portable projectors may co-operate and turn out an interchangeable product.

(3) That the term "Portable Projector" and its definition be added to the Society's list of motion picture nomenclature.

I also submit the following film standard as per drawing, which seems to me to fully meet all requirements. With a standardized non-inflammable film, universally adopted by all manufacturers, a film that will, if possible, permit printing by reduction from standard negatives—I see no reason why the portable projector may not come into its own.

It could thus enter its field of service, unhampered by the stigma of criminal risk; safe-guarding its users as conscientiously as does its big brother—the professional projector.



Theoretical vs. Practical as Applied to Standardization and Some of the Things to be Considered as Proper Subjects for Standardization

By F. H. RICHARDSON

In approaching the problem of applying suitable standards to appliances in common use in the motion picture industry, it is well to remember that the thing which may seem precisely right when viewed from the standpoint of theory may fail utterly under the crucial test of actual practice. This is particularly true where the appliance is to be placed in the hands of an incompetent man, or a man of mediocre ability.

In this connection it is well to consider that insofar as machinery and appliance for the theatre operating room be concerned, a large proportion of it will be handled by men of relatively small ability in the handling of machinery or optical appliance; a very considerable proportion will be handled by men of no ability whatever and only a relatively small percentage will be placed in the hands of those who could by any stretch of imagination be termed experts. Remember, gentlemen, this is the *condition* which prevails and is not easily altered; hence it must be reckoned with. It would be foolish indeed to ignore this condition merely because it ought not to exist. It *does* exist and will continue for at least several years to come.

The effect upon standardization of this condition is, that in operating room machinery standardization, we must studiously avoid the too-delicate. For instance, the spindle which might be perfectly capable of carrying its load under proper conditions at 5-16″ diameter, may carry it far better at 3-8″, 7-16″ or even 1-2″ diameter, if it is to be placed in charge of a man who knows little or nothing about proper lubrication and who is careless and generally incompetent. In other words, it will be well to lean always to the side of generous dimensions in operating-room moving machinery parts. In the fixing of standards for operating-room machine parts we must, for the present at least, take into consideration the conditions under which such machinery will, or may work, else difficulty will surely be encountered.

The question of which particular things require standardization is one which cannot be answered by any one man. In my opinion, the standardization of projector parts should only be undertaken upon the recommendation of the committee on projection machines. This committee should hold meetings and recommend to the body such standards as may seem in its wisdom to be right and proper. Unless this is done, I believe there will be more or less confusion and liability to error. The same applies to cameras, optical appliances and such other things as are covered by committee.

I would further respectfully suggest that any proposal of a standard presented to the body by an individual be not acted upon finally until it has been referred to the committee within whose jurisdiction it

comes, or to a special committee, of which he shall be a member, the committee to consider the matter and make its recommendation at the next regular meeting.

The foregoing is, of course, a digression, for which I trust I may be pardoned because of its seeming importance.

In general there are several things not coming within the duty of any committee, which ought to receive attention from this body, unless it be held that camera speed falls within the field of the committee on cameras.

Camera speed is, perhaps, the one thing needing the attention of this body more than anything else. Lack of uniform camera speed is doing literally tremendous damage to the silent drama, both artistically and physically. The present condition is that different directors or producers adopt their own individual views as to camera speeds, ranging all the way from sixty feet of film per minute to as high as seventy-five. This would be bad enough, but to it is added the variation in speed by individual camera men, who often take scenes intended to join each other in the finished product. This variation runs as high as, in extreme cases, five each way from normal, making a total variation as between adjoining scenes, of ten feet per minute—a variation of two to five feet is quite ordinary. Projectionists, as a rule, either do not or are not allowed by circumstances (running to "schedule") to vary the speed of projection to suit variation of speed as between various scenes in a film; also the schedule for the show is made up without knowledge as to the speed at which the film (footage always known, at least approximately) was taken, hence the reproduction of the photoplay upon the screen is a sort of haphazard, happy-go-lucky performance, which can only be right by pure accident.

With camera speed standardized, the proper time for the proper artistic reproduction upon the film would merely be a matter of dividing the total footage by number of feet per minute standard. Without entering into detail, this would also work out to immensely lessen the physical injury to films, now mounting into the tens of thousands of dollars per day.

For several reasons I would respectfully recommend to this body a higher standard per minute for camera and projection machine. Our present rate is too slow with present powerful illumination and semi-reflective screens. It is not sufficiently high to eliminate flicker under those conditions, especially if the local shutter conditions be bad. Seventy will, on the other hand, place no unduly heavy burden on the film itself, or upon projection machinery, and will eliminate flicker in all but the very worst cases.

Another thing which might well receive attention is the minimum distance from front row of seats to screen, which should, I think, be based upon picture size, but with an absolute minimum of fifteen feet for a ten-foot picture, with one foot of added distance for every foot of added width up to twenty feet.

Exit signs is still another thing which cries to heaven for standardization, though anything we might do in this respect would be at the mercy of ill informed officials and law makers. But this does not ex-

cuse this body from acting. I would respectfully suggest the following: the letters E X I T on plain ground glass, the letters to be of size to comply with local law, and to be blocked out in black, so that light shows through the letters only. Behind the ground glass bearing the letters and between the letters and the illuminant, there to be a sheet of dark ruby glass, or two thicknesses of standard photographers ruby glass. This allows only the letters E X I T to be visible to the audience and in dark red.

Still another proper subject for standardization is the width of black border for screen.

In the operating room itself, aside from machinery, etcetera, the observation ports are in sad need of standardization, both as to width and height from floor, though the latter is difficult by reason of projection pitch. The operating room size also needs attention. Present standards were adopted while projectors were very much smaller than at present. Operating rooms should be not less than nine (9) feet front to back; ten (10) would be better.

Operating room ventilation standardization is necessary, both from the standpoint of health and fire hazard. The state law of Massachusetts will form an excellent basis for study of this subject.

There are other things I might mention, but it seems to me I have said enough (perhaps you may think too much) for one time. I would, however, again utter warning as against adopting standards from the purely theoretical point of view. I have for many years preached to projectionists the gospel of combining theory with practice. I now respectfully ask this body to apply that doctrine in reverse. Be very certain that practice, *as it is*, will combine at least fairly well with theory, before setting up a standard which, while theoretically perfect, will fail when placed in actual operation under the conditions prevailing.

Incandescent Lamps for Motion Picture Service

By A. R. Dennington

ARRANGEMENT OF LIGHT SOURCE

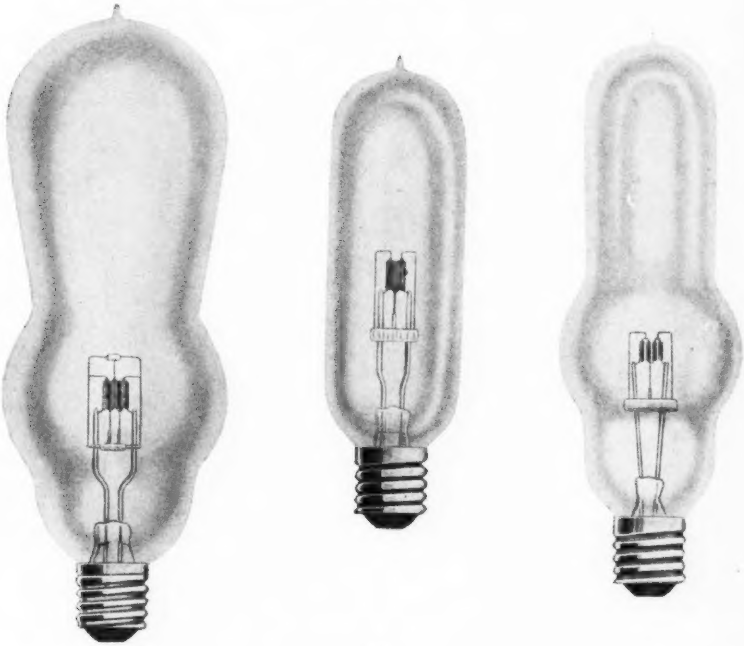
In the development of an incandescent lamp for motion picture service, it is essential to concentrate the light source as much as possible because no condensing system can collect and utilize the rays of light from an extended source. The problem that comes up is, therefore, that of getting as much filament as possible within a given area and arranging this filament in such a way that there will be maximum illumination in the direction in which it can be utilized.

There are in general two methods which suggest themselves for the arrangement of the filament. One method consists in arranging the coils in series and placing the various sections close to each other and practically parallel. This series of coils may be arranged either in planes at right angles to the line of projection, or in a more or less complete arc of a circle. Arranging the coils in the arc of a circle has the advantage of placing each element of the filament equally close to the focal point of the optical system. However, it has the disadvantage that no element of the filament can be placed exactly at the focus and therefore no element is operating at the best possible efficiency for the system. The arrangement of the filament sections in a plane or planes perpendicular to the line of projection has been found to be more satisfactory than the circular arrangement, as it makes possible a more uniform field or beam than can otherwise be obtained. There are, however, spaces between the filament sections which are not sources of light and the result of this is that the screen may have light and dark areas corresponding to the filament areas.

The second method of arranging the filament is to connect the sections in parallel with very small space between them. This arrangement permits of a larger amount of filament within the given area but it has the disadvantage of requiring a high current which is liable to cause heating of the lamp seal as well as the wires and contacts. Any sagging of the coils tends to short-circuit to a greater or lesser extent portions of each section, as the current passes from a turn of one coil to a turn of another coil without passing around the helix, thus reducing the lamp voltage and the candle power as well. If the coils are spaced far enough apart so that there is no danger of the sections short-circuiting by contact with each other, there is little or no advantage of the parallel arrangement of coils over the series arrangement.

In order to obtain some of the advantages of practically an unbroken wall of filament and also retain the advantages of series connected coil sections, an arrangement of the filament has been developed which places the coil sections in two parallel rows, with the coils in the back row opposite the spaces between coils in the front row. This arrangement of the filament presents a solid wall along the axis

of projection as shown at *a* Fig. 1. However, as the condenser picks up light from angles up to 40° there are certain portions of the condenser which receive light only from the front rows of coils, the rear coil sections being hidden behind the front row. A condition of this kind necessitates a somewhat larger amount of energy supplied to the coil for a given screen illumination. This increase in the power necessary is considered of secondary importance, the primary requisite being to get as much illumination as possible on the screen. The two rows of filament are placed as close together as practicable in order that all sections of the light source may be as near as possible to the focal point. Lamps of smaller wattage can have the filament arranged in a single row or plane as shown at *b* and *c*.



a *b* *c*

FIG. 1

The useful area of light source varies with different condensing systems and different projection lenses. Under a given set of conditions, the useful projected area of filament can be determined by testing back from the screen by means of a lamp. A lighted lamp is placed at each corner of the screen after the objective lens has been carefully focussed and the condensers adjusted so as to give the best illumination on the screen. The light source is then removed from behind the condenser and a test plate placed in the position of the filament. The

lighted area on this test plate indicates the area which can be used in illuminating the screen. When the test lamp is placed close to the corners of the screen the lighted area on the test plate shows the cutoff due to the corners of the aperture plate. When the test lamp is moved in from the edge of the screen the spot projected back to the test plate is circular.

A number of tests were made on different types of condensers including the usual plano-convex condensers and also the special Corning corrugated lens of the Fresnel type. With a pair of plano-convex condensers having a 5½″ focus lens toward the light source and a 7½″ focus lens toward the aperture plate, the following results were obtained:

The light source, *a* (Fig. 2), was placed 85 millimeters from the face of the 5½″ condenser (b), and the distance from the face of the other condenser (c) to the aperture plate was 234 millimeters. The two

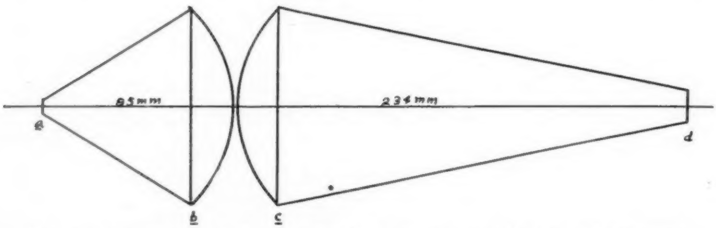


FIG. 2—Arrangement of Plano-Convex Condensers in test for size of light source

condensers were placed so that there was about 1 millimeter clearance between the convex surfaces. Under these conditions, the area of the light source as measured on a test plate is 11 by 13 millimeters, *a*, Fig. 3. The setting given for the condensers and light source were determined after a number of trials and were found to give the best results, both from the standpoint of illumination and uniformity of screen. The total illumination delivered on the screen from a 1200 watt lamp operating at an efficiency of .477 spherical or .315 horizontal watts per candle was 754 lumens. In testing back from the screen to determine the area of the light source, the test lamp was placed close to the screen. When the lamp was placed close to the objective lens, a different light source area was obtained as shown in *b*, Fig. 3. In this case, the illuminated area on the test plate consisted of two parts, one part essentially the same size as before but surrounded by an area of lower intensity. This area measured about 22 by 19 millimeters. These tests indicate that the light source would have a useful area of 11 by 13 millimeters. However, it is advisable to make the source somewhat larger than this, hence the dimensions adopted are about 16 millimeters for the horizontal dimension and 13 millimeters for the vertical dimension of the light source.

In order to determine the effect which would be obtained by back testing through a corrugated condenser having equivalent foci of 2½″ and 8,″ the same method was used as in the preceding test. The

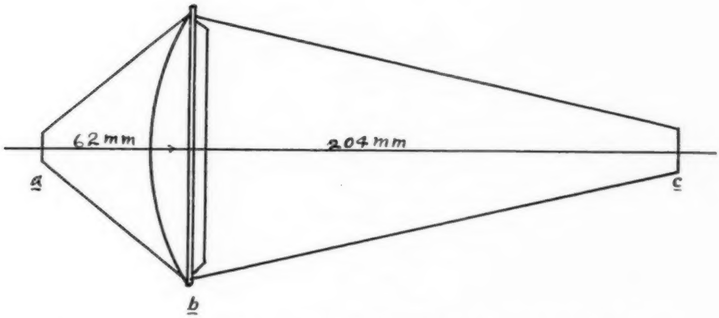


FIG. 4—Arrangement of Corrugated Condensers in test for size of light source

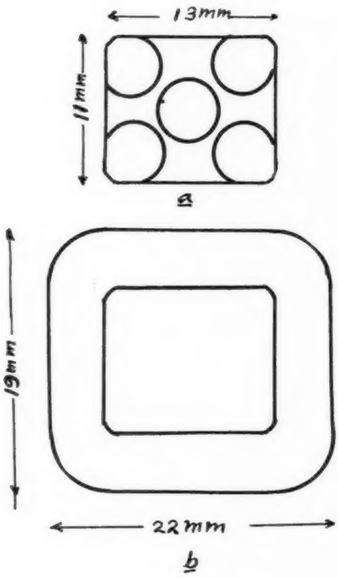


FIG. 3
Light source area for 5½″ x 7½″
Plano-Convex Condenser System

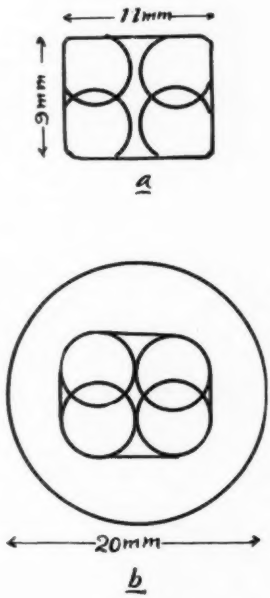


FIG. 5
Light source area for 2½″ x 8″
Corrugated Condenser

lamp was set up so as to give the best possible screen, which condition was obtained when the light source was placed at the $2\frac{1}{2}''$ focus and the distance to the aperture plate was practically $8''$, Fig. 4. Under these conditions the lamp which had been used in the preceding test was operated at the same efficiency as before and gave a screen illumination of 616 lumens. When the lamp was removed and the light source at the screen was used for back testing, the lighted area on the test plate was 11 by 9 millimeters, *a* Fig. 5. When the test lamp was moved up to the end of the objective lens there was still an area of 11 by 9 brightly lighted on the test plate, but this was surrounded by a circle *b* 20 millimeters in diameter. It was noted that the circles which were projected back from the test lamp were somewhat larger than with the plano-convex condenser, showing that the corners of the screen were illuminated by a somewhat greater proportion of the light source. The test also indicated that the corrugated condenser did not utilize as much of the filament area as did the plano-convex condenser.

EFFECT OF MIRROR ON LAMP RATING

In order to determine the effect which the mirror has on the temperature of the lamp filament when the latter is placed at the center of curvature of the reflecting surface, tests were made on both monoplane and biplane lamps. The lamp ratings given in Table 1 were taken without a mirror focused on the lamp filament. Temperatures were measured both with and without the mirror as shown by the values in the last two columns.

Table 1—Effect of Mirror on Filament Temperature

LAMP	W.	V.	Amps.	H. CP.	H. W. P. C.	S. CP.	S. W. P. C.	Temp. Without Mirror	Temp. With Mirror
Monoplane	806	26.	31.	2560	.315	1480	.544	3200°K	3245°K
Biplane	1192	42.3	28.2	3900	.3055	2500	.477	3275°K	3325°K

It will be noted that the effect on the temperature of the filament is essentially the same with the monoplane and biplane construction. This is probably due to the fact that in the monoplane construction the coil sections are spaced as closely together as practicable so that the distance between coils is considerably less than the diameter of the coil. The reflected image of the coil, therefore, instead of passing between the coils comes back on the coil to a greater or lesser extent. In the biplane lamp, the reflected image of the coil comes back partially on some portion of the coil and partially on the spaces between so that in the two cases, the temperature conditions are very nearly the same, the table indicating differences of only 5° with the two coil constructions. If the spaces between the coil sections of the monoplane coil were increased the temperature would probably be somewhat less than indicated, but the screen illumination would also deteriorate because it would show the spaces between the coils.

The effect of a properly focused mirror on increasing the illumination on the screen is indicated in Table 2.

Table 2—Effect of Mirror on Screen Illumination

LAMP	CONDENSER	MIRROR	LUMENS
Biplane No. 21-10	Corning—2½″ x 8″	None	467
" " 21-10	" —2½″ x 8″	M. E. 8″	584 Gain by mirror 24.6%
" " 21-10	Plano-Convex 5½ & 7½	None	544
" " 21-10	" " 5½ & 7½	M. E. 8″	712 Gain by mirror 30.8%
" " 21-11	Corning—2½″ x 8″	None	556
" " 21-11	" —2½″ x 8″	M. E. 8″	681 Gain by mirror 22.5%
" " 21-11	Plano-Convex 6½ & 7½	None	575
" " 21-11	" " 6½ & 7½	M. E. 8″	686 Gain by mirror 19.3%
		Average Gain by mirror 24.5%	

The mirror in each case was a Macbeth-Evans spherical mirror, having an 8″ diameter and 5 5-8″ radius of the reflecting surface. The gain due to the use of the mirror in the tests ranges from 30.8% to 19.3% and gives an average gain of 24.5%. All of these tests were made with biplane filament lamps. Two different lamps were used and two different combinations of plano-convex condensers. A further test was made using biplane lamp No. 21-10 in order to determine how much the current supplied to the lamp could be reduced in order to give the same illumination as was originally obtained with this lamp without the mirror. This test showed that changing the current from 28 amperes on a lamp used without a mirror and giving a screen illumination of 544 lumens to 27 amperes on the same lamp with a mirror, gave a screen illumination of 564 lumens. This change in current in the lamp is equivalent to a change of about .06 in spherical watts per candle. However, there is a gain due to the use of the mirror which is not accounted for by the change in current and the resulting change in temperature of the lamp filament. This gain is due to the light from the reflected image of the filament which tends to give a more uniform light source so that the illumination on the screen is more uniform and of higher intensity than can be obtained from the filament alone.

CONDENSER SYSTEMS AND OBJECTIVE LENSES

A number of different condenser systems have been tried out in the development of apparatus for the use of incandescent lamps in motion picture projection. The two which have given the best results are the corrugated type of condenser and the plano-convex condenser systems. Each of these condenser systems possess some advantages and also some disadvantages in comparison with the other, and it is a matter of choice as to what points should be sacrificed in making a decision as to the type of condenser. One advantage of using the plano-convex condenser system is that the working space between the lamp house and the head of the motion picture machine is great enough to permit of easy manipulation of the framing lever or to make any adjustment to the film which may be necessary. There is also another advantage in that the angle at which the light rays converge is more acute and therefore there is less loss in picking up the cone of light beyond the aperture plate and collecting this cone in the objective lens. This is especially true where a fairly long focus objective

lens is used. Motion picture machines which are in use at the present time are constructed with a lens tube or holder about 2″ in diameter. If a lens larger than this holder is to be used, it is necessary to have an adapter, which reduces the opening to the lens to the 2″. In this way, a part of the area of a 2½″ diameter lens is unavailable because the light rays strike the sides of the holder before reaching the lens. The disadvantage of the plano -convex condenser is that there is some tendency to show a more or less imperfect image of the coils of the lamp filament on the screen. This tendency can be reduced to a minimum by careful focusing of the lamp and by use of a mirror back of the filament. It is possible to produce a screen which is so nearly free from iridescent streaks that it is not in the least noticeable when a picture is being shown, though there may be slight traces of the streaks on the open screen when there is no film in the machine. Lantern slides can be shown with the plano-convex condensers and this is a condition which must be considered. The corrugated condenser has the advantage of giving a somewhat more uniform screen illumination than can be obtained with the plano-convex system. It has the disadvantage of requiring a very short working space between the lamp house and the head of the motion picture machine. Lantern slides cannot be shown with this condenser and an auxiliary set of plano-convex condensers is necessary. The condenser also has such a short focus that the rays of light converge at a much more obtuse angle than the rays from a plano-convex condenser and therefore a greater portion of the cone of light passing through the aperture plate is lost and is not picked up by the objective lens.

SHUTTERS

The use of incandescent lamps on alternating current circuits will result in improved screen illuminations because of the fact that the filament stores up heat and maintains a practically uniform temperature throughout the current cycle. In an arc lamp, the intensity of light varies as the current alternates. It is because of this periodic variation in the arc that it is necessary to use a two-wing shutter on motion picture machines which are being operated on 60 cycle alternating current circuits. With a two-wing shutter, the picture is normally cut off 32 times per second. This frequency of cut-off is so far different from the frequency of the light variation due to the alternating current that there is no tendency for the two to come into synchronism. However, if a three-wing shutter is used the picture is cut off 48 times per second. This frequency of cut-off is so near the frequency of the current that there is a periodic variation in the screen appearance due to the fact that the light is dim because the current is near zero value during the time that the shutter is open and later the picture is cut off entirely by the shutter wing. Later the light is bright while the shutter is open and the result is a periodic variation in the brightness of the picture. It will be dim for a short space of time and then it will be bright for a corresponding period. This condition has led to the adoption of the two-wing shutter as the standard for alternating current circuits. The two-wing shutter possesses the disadvantage of operating at such a low frequency of cut-off that there is

usually a decided appearance of flicker on the screen. With a gas-filled incandescent lamp on an alternating current circuit the light is steady and therefore a three-wing shutter can be used with the result that the frequency of cut-off of a picture is sufficiently high so that there will be no noticeable flicker.

In the use of wide aperture objective, to secure as much illumination on the screen as possible, the shutter should be considered. If the shutter is not adapted to the wide aperture lens, it will not cut off the light from the screen during the period of picture travel and there will be the appearance of a travel ghost. This may be seen especially when titles are being shown as it tends to cause a stringing out or fuzziness of the tops and bottoms of the letters. Most of the shutters for machines have been designed for use with the smaller lenses and the wings are not wide enough to take care of the wide aperture lenses. If the shutter diameter remains unchanged and the lens is very greatly increased, the angle through which the shutter must move in order to cut off the light from the screen is decidedly increased, thus resulting in a slower cut-off and a corresponding reduction in the time that the full lens aperture is utilized while the film is stationary. The use of a shutter with a diameter correspondingly larger is desirable where a wide aperture lens is used, though in most cases such a change in the shutter size cannot be made conveniently. The only thing which can be done to minimize the difficulty is to proportion the wings of the shutter so as to eliminate the travel ghost and at the same time get as much light on the screen as possible.

SCREEN ILLUMINATION

The useful light which is delivered to the screen is the final test of the effectiveness of any system of condensers and lenses which may be used. The object is always to produce the brightest and most uniform screen possible with a given source of light. It is no disadvantage to have the illumination in the center of the screen somewhat greater than near the edges because the greater part of the action in the pictures is well toward the center; however, there should be sufficient light at the edges to show up details and the screen should not be so uneven that it is noticeably brighter in the center than at the edges especially when titles are being shown. If the difference between the center and the edge illumination is too great, titles will show up clearly in the center and will fade off toward the ends of the lines so that it is difficult to read the complete message.

A typical screen illumination is shown in Fig. 6. The figures in the center of each square represent the actual foot candles on a small screen having an area of 27.75 square feet. The total illumination delivered to this screen is 693 lumens. The intensity of illumination in the corners is approximately two-thirds the intensity in the central portion of the screen and this ratio is not too great for the satisfactory projection of pictures.

The color of the light delivered by an incandescent lamp has a warmer tone than the light from a carbon arc and therefore the pictures do not have that hard chalky appearance which is sometimes noticeable in pictures projected by high-powered arcs. As the illumi-

20	24	2.37	19
22	27	32	2.35
23	32	27	23
20	2.75	25	20.5

FIG. 6—Diagram showing foot candle intensities on screen having an area of 27.75 sq. ft.; 693 lumens

nation is steady the eye can be more comfortably focused on the picture than where the light intensity is varying as is always the case where arcs are used.

A comparison of the intensities obtained on a screen with a 40 ampere direct current arc and 1200 watt lamp is shown in Fig. 7. These intensities give approximately equally satisfactory pictures; that is, the audience could not determine which lamp was in use. In this test the illuminometer was arranged so that its field of view covered practically the entire surface of the screen and readings were taken at intervals of 15 seconds for a period of 10 minutes. The scale used is an arbitrary scale and does not show the actual foot candle values of the light reflected from the screen.

LAMP-HOUSE EQUIPMENT

When the filament of an incandescent lamp is once placed at the proper point in the optical system it remains in this position for the life of the lamp. Changes in the focus are necessary only when lamps are changed. For this reason it is possible to adjust a lamp so that the filament occupies a predetermined position with respect to a base plate or holder which can be slipped into the lamp-house or removed at will. After the filament has been adjusted with respect to this holder, the lamp and holder can be very quickly placed in service in the machine in case of a burnout. The only thing necessary is to remove the burned out lamp and holder and substitute the new holder with its lamp properly adjusted.

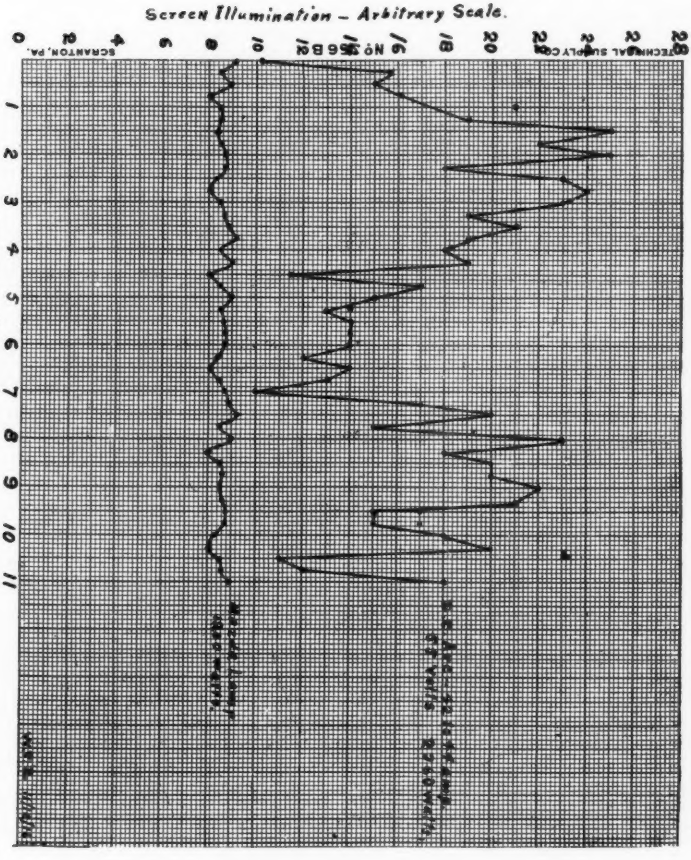


FIG. 7—Variation in screen intensities D. C. arc and Tungsten lamp

Mechanism has been developed which permits the focusing of lamps entirely independent of the optical system of the machine. It has been demonstrated by actual test that more uniform results can be obtained in this way than can be obtained by focusing each individual lamp in the system by judging the appearance of the screen by the eye. There are certain modifications of this equipment which include a part or all of the features which have been outlined.

ELECTRICAL CONTROL EQUIPMENT

The lamps for motion picture projection are operated at extremely high filament temperatures. It is necessary, therefore, that the current supplied to the lamp be closely regulated as, otherwise, satisfactory lamp performance cannot be secured. If the current is reduced below that at which the lamp is rated the intensity of the light is diminished while if the current is increased above the rated value there is danger that the lamp may fail very shortly.

In order to keep the current at the desired value it is essential that an ammeter be included in the lamp circuit. Where the lamp can be supplied from an alternating current circuit it is possible to use a transformer equipped with an ammeter and a regulating device. The regulating device may consist of a switch which connects different taps of the secondary to the lamp in order to obtain the current control, or may consist of an adjustable reactance. The reactance method of controlling the current has the advantage of permitting very accurate adjustment of the current and voltage. This is of primary importance and the transformer is not a serious disadvantage. In fact under the worst conditions the power factor of the control equipment for incandescent lamps will be higher than the power factor of arc lamps with reactance coils which are often used. The power required by this lamp is less than the power required by the arc, so that existing circuits in the theatres will be ample to supply the new lamp and the voltage drop will be less than when the arc is used.

It is important that the rush of current through the lamp at starting be kept fairly low in order to protect the ammeter and reduce the danger of cracking the lamp seal at the point where the leading-in wires pass through the glass. The resistance of the lamp filament is very low when the filament is cool and as the filament is large there is an appreciable time before it heats up so as to limit the current. If no method is used to limit the starting current the initial rush is momentarily many times the normal lamp current.

Some Consideration in the Application of Tungsten Filament Lamps to Motion Picture Projectors

By L. C. PORTER *and* W. M. STATES

The fact that there are today in operation approximately one thousand motion picture machines using the tungsten filament lamp as a light source proves that the incandescent lamp is a success in this field. The history of the developments which were gone through to achieve this success is very interesting. Some of the lamps and apparatus, which a short time ago seemed marvelous, today appear almost crude. However, we shall not take your time to describe the discouragements and the achievements along this line during the past three years. Nor shall we devote much time to description of the fundamental differences between the arc and the incandescent systems. This data is already more or less familiar to you, through papers presented before your Society, through articles in the trade journals, and through commercial advertising of the concerns manufacturing projection equipment.

In starting anything new there are always interesting developments which come through practice. Unforeseen difficulties arise and new methods of operation are established. It is the purpose of this paper to call attention to some of the practical considerations which have been found of material assistance in getting the best out of the incandescent projector. We wish to present data which will assist the manufacturers of motion picture equipment to realize the great advantages of accuracy in the optical system. We also hope to describe little "tricks of the trade" which will be of service to the users of projection equipment.

Few engineers or operators realize fully how closely it is possible to work with the incandescent system. In the arc system there must be more leeway. The carbon crater covers considerably greater area than is actually necessary, so far as light utilization alone is concerned. However, the arc is more or less unstable. It wanders around, and hence some allowance must be made to meet that condition. Shading by the negative carbon, and feed requirements constitute a very complex handicap. In other words, with the arc it is necessary, on account of these variations, to use larger carbons and more power than would be required if the arc could be held in a fixed position. Each optical system has a definite area over which it will pick up light. Any flux originating outside of that area adds little to the resultant screen illumination. Let us examine (Fig. I), a diagrammatic sketch of the optical system of a moving picture machine.

Assuming that the light originates from the arc A the paths of the extreme rays may be indicated by lines B and C, terminating on the motion picture screen. Suppose we have another ray of light, D, originating a considerable distance outside of the arc crater. It will be bent by the condensers similarly to rays B and C, and therefore, will not fall on the objective lens and will not reach the screen. This ray D

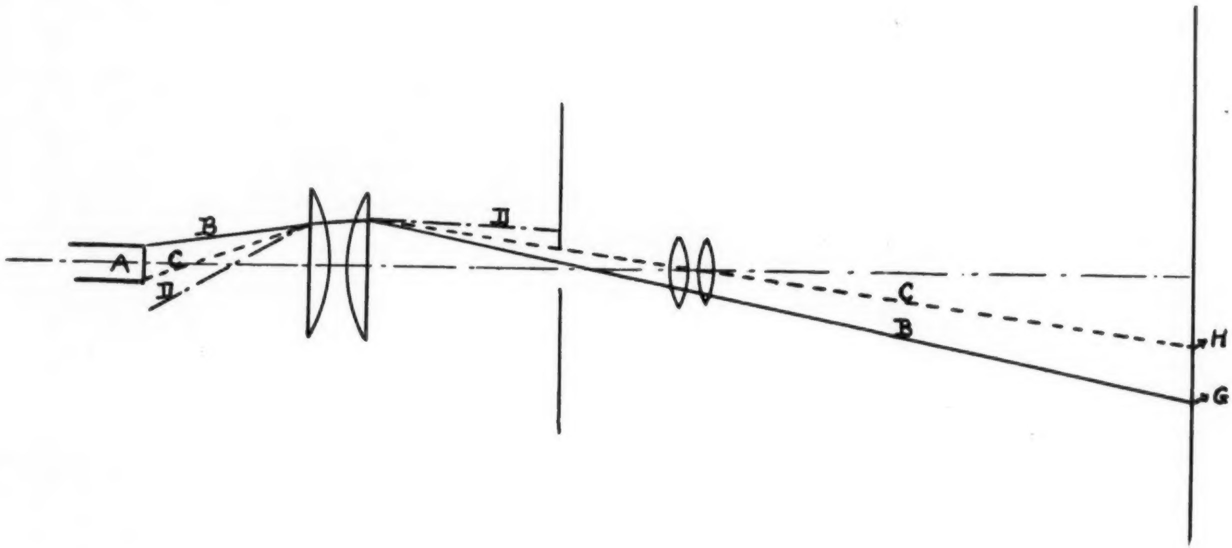


FIG. 1

of light originates too far from the focal point of the condenser to be of service. It, therefore, becomes evident that there is a limit to the size of light source which can be utilized. There is a very simple method of determining that size. Let us send the light rays backwards, *i .e.*, suppose the screen were illuminated by another machine or suppose it were made of translucent diffusing glass and lighted from behind, then the ray of light starting at point G on the screen would follow back along the path of the previou ray B. Similarly a ray originating at point H, and so on for every point on the screen. If we replace the arc crater by a piece of ground glass or oiled paper, an image of the screen will be formed on this glass. By moving the ground glass forward and backward, a point will be found where this image will be smallest and its edges sharp. That lighted area then is the maximum size area possible to utilize as a light source. All light rays originating within that area, and falling on the condenser will be projected on to the screen. It is not always convenient to light the screen by another machine and even if it is, the intensity of the reflected light finally reaching the ground glass is low. A more convenient method is to place a piece of translucent diffusing glass (such as heavy density opal) directly in front of the objective lens and hang an ordinary tungsten filament lamp in front of this, (Fig. II).

This method of determining the useful size of light source is called back-testing. Let us take a specific example, a machine equipped with a 4½″ diameter, 6½″ focus rear condenser lens and a 4½″ diameter, 7½″ focus front lens and a 1¾″ diameter, 5½″ focus projection lens. Back-testing it we found the maximum light source size to have an area of .188 sq. in. In practice, this machine operates with 5-8″ diameter carbons burning at an angle. The actual area of the crater is .368 square inches, .18 square inches or 95% greater than the maximum, useful, light source area. This extra amount is, however, considered necessary due to the utter impossibility of keeping the arc crater fixed in one spot, and on account of the shading by the negative carbon (which is most at low currents.)

Having this extra area of light source available, slight variations in alignment of the optical system do not materially affect the total amount of resultant screen illumination, though colored borders and ghosts are apt to appear. This, however, is not so with the incandescent lamp. The filament of that light source is of fixed area and remains *exactly* where it is put. Under these conditions a filament has been designed to fill exactly the maximum useful area of the lens system. This area for the lens system at present in use is a square 4-10 of an inch on a side or having a total area of .16 of a square inch.

Let us suppose, for example, that in setting up the lamp in the machine an operator fails to center the lamp filament properly in the 4-10 of an inch useful area. Suppose it is 1-10 of an inch to one side. We then have the condition shown in Fig. III, only ¾ of our light source is within the useful area. This will result in a very material lowering of the screen intensity. Not only is there a loss of light, due to a portion of the filament being outside of the useful area, but also the beam projected by the condenser is bent to one side, and hence much light is spilled on the aperture plate instead of passing through the aper-

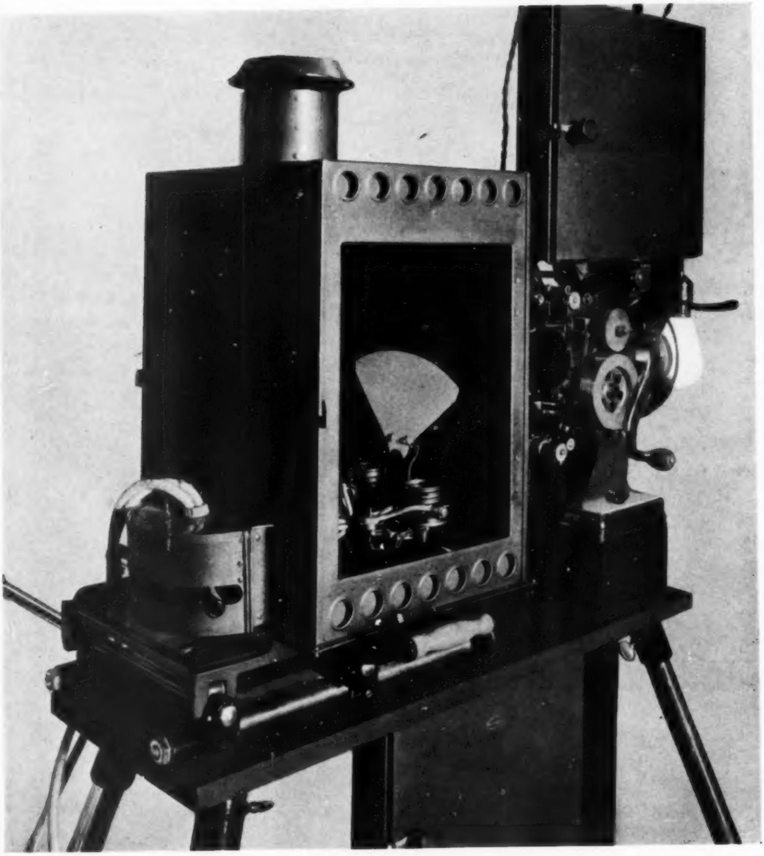


FIG. 2

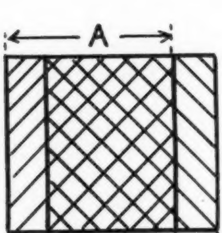


FIG. 3

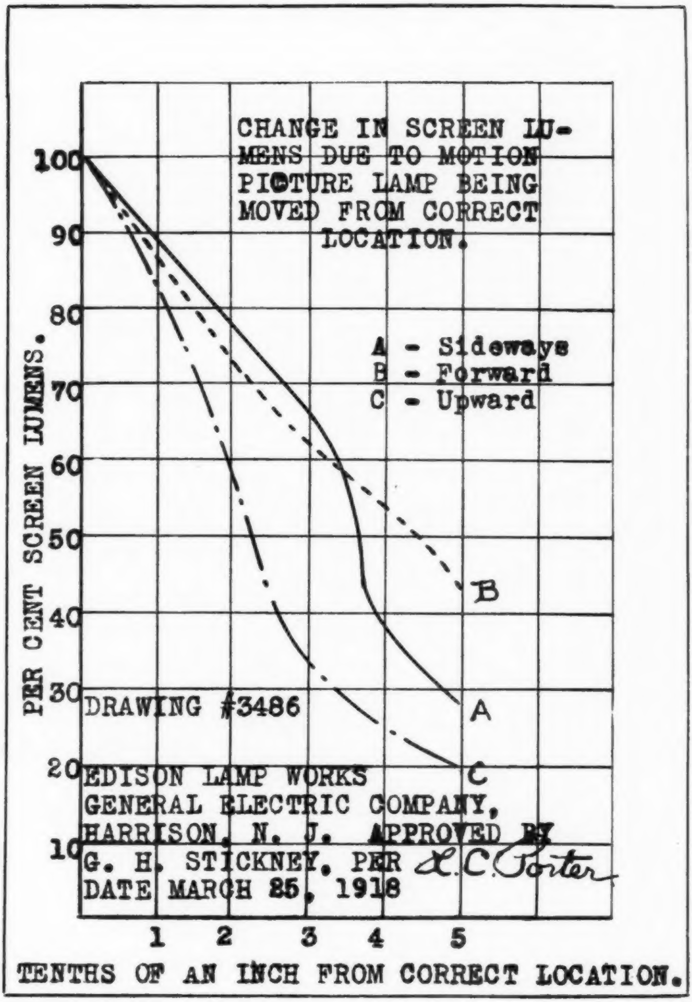

CHANGE IN SCREEN LUMENS DUE TO MOTION PICTURE LAMP BEING MOVED FROM CORRECT LOCATION.
A - Sideways
B - Forward
C - Upward
PER CENT SCREEN LUMENS.
100
90
80
70
60
50
40
30
20
10
B
A
C
DRAWING #3486
EDISON LAMP WORKS
GENERAL ELECTRIC COMPANY,
HARRISON, N. J. APPROVED BY
G. H. STICKNEY, PER L.C. Porter
DATE MARCH 25, 1918
1 2 3 4 5
TENTHS OF AN INCH FROM CORRECT LOCATION.

FIG. 4

ture. To illustrate this the authors' took a motion picture lamp, focused it in a moving picture machine and measured the screen illumination. The lamp was then moved to one side in steps of 1-10″ at a time. The following results were obtained:

Filament Centered	Relative light on Screen (Lumens)	100
" 1-10″ off center	" " " " "	88.5
" 2-10″ " "	" " " " "	77.0
" 3-10″ " "	" " " " "	66.0
" 4-10″ " "	" " " " "	38.0
" 5-10″ " "	" " " " "	28.0

Similar results maintain if the filament is too high or too low. Proper centering of the light source is therefore essential to efficient projection. Very material losses also occur if the light source is placed too far ahead or too far behind its proper location with respect to the condenser. A test showed these losses to be as follows:

Filament in Focus on Shutter	Relative Light on Screen (Lumens)	100
" 1 10″ ahead of proper location	" " " " "	88
" 2/10″ " " " "	" " " " "	72.5
" 3/10″ " " " "	" " " " "	63
" 4/10″ " " " "	" " " " "	54
" 5/10″ " " " "	" " " " "	44

No spherical mirror was used in this test.

If the lamp filament is moved back of this position, an increase in screen illumination is obtained up to the point where the filament images are focused sharply on the aperture plate. Here, however, the unevenness of the screen is so great as to be objectionable. Probably a compromise between maximum evenness and maximum illumination is acceptable. Such a compromise will result if the filament is moved back about ¼″ from the point where it focuses most sharply on the shutter.

The following method may be used to locate the lamp filament:

Light the lamp and set it approximately in its operating position. That is 2″ in back of the edge of the 3½″ diameter prismatic condenser or 2½″ in back of the edge of the 4½″ prismatic condenser. Place the lamp so that the plane or broad face of the filament is parallel to the front face of the condenser.* Center the lamp with respect to both sides and up and down by adjustments provided on the machine for that purpose. When the filament is properly located in the horizontal

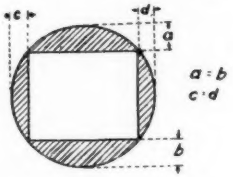


Fig. 5

*Scale drawings of this set-up are furnished by the manufacturers with instruction sheets accompanying motion picture equipment.

or vertical directions, the spot of light on the aperture plate will have equal width on each side of the aperture and also above and below the opening, (Fig. V) "c" should equal "d."

If these settings are not correct, a larger spot is necessary to cover the aperture. For example, with the spot properly set it need be but 1¼" in diameter to cover the aperture. This means a total area of 1.21 square inches, of which 0.75 square inches of light goes through the aperture and 0.46 square inches, or 36% is wasted (Fig.VI. A). If the spot is but 1-8" too low or too high, a 1 7-16" diameter spot of light is necessary to cover the aperture, which means an area of 1.35 square nches, hence practically 50% of the available light flux is wasted (Fig. VI. B). A similar effect occurs if the spot is too far to either side.

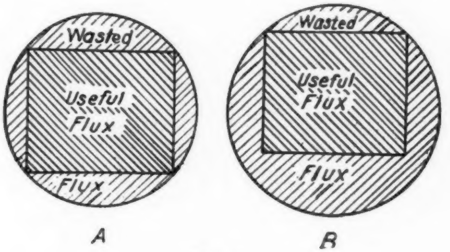


Fig. 6

By means of other adjustments the lamp can be brought closer to or moved farther away from the condenser. To determine when the lamp is the correct distance from the condenser, place one wing of the rotating shutter in front of the objective lens. An image of the lamp filament will appear on this wing. This adjustment can be more satisfactorily made if the spot of light thrown by the mirror is not on the aperture plate in addition to that projected by the condenser. The mirror should be removed or turned to one side. By moving the lamp forward and back, a point will be found where the image is sharpest. This is the correct operating position of the lamp. The appearance of the spot on the shutter wing should be as shown in Fig. VII. A.

The accurate setting of the spherical mirror is also of great importance. The mirror performs two functions: It redirects that portion of the light from the lamp filament emitted backward and adds it to that projected directly on to the condenser. By so doing increases as high as 60% in screen illumination have been obtained. Secondly, the reflected light fills up the spaces between the filament coils and thus evens up the resultant screen illumination.

After placing the center of the reflector in a horizontal plane with the lamp filament, and the center of the condenser, the reflector should be moved forward and backward by means of adjustments provided for that purpose, until the reflected spot of light on the aperture plate is the same size as that projected by the condenser, in which position the filament image on the shutter will be of maximum sharpness. The mirror is then twisted or moved slightly sideways, until the dark

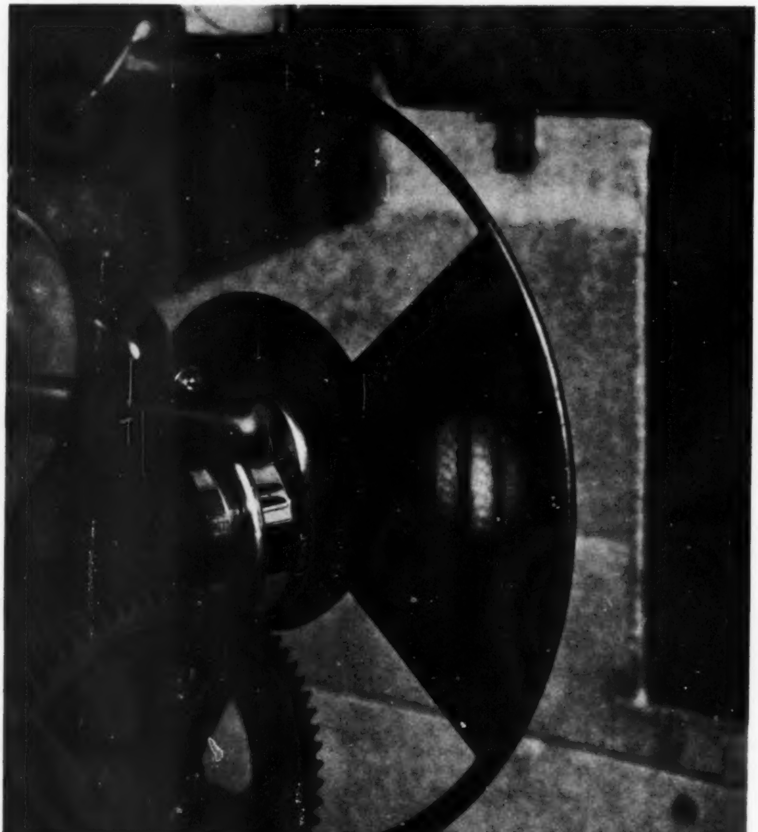


Fig. 7-A

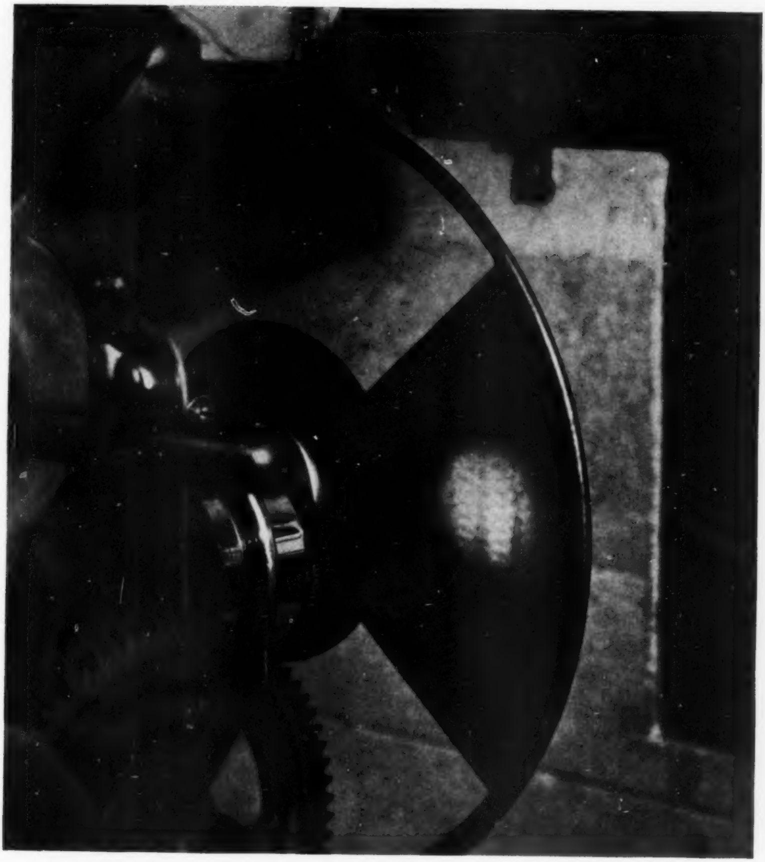


Fig. 7-b

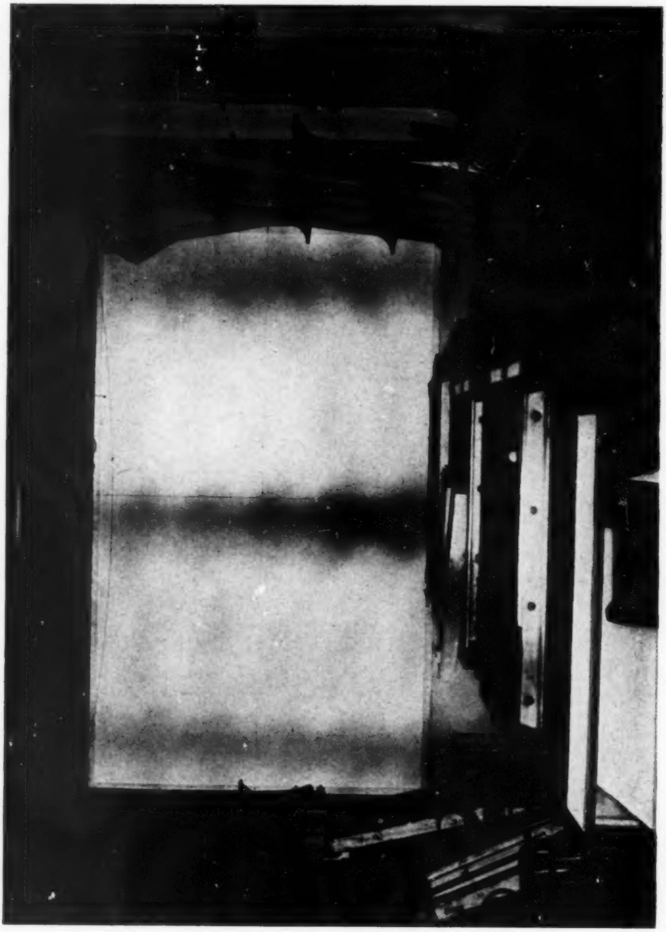


Fig. 9-a

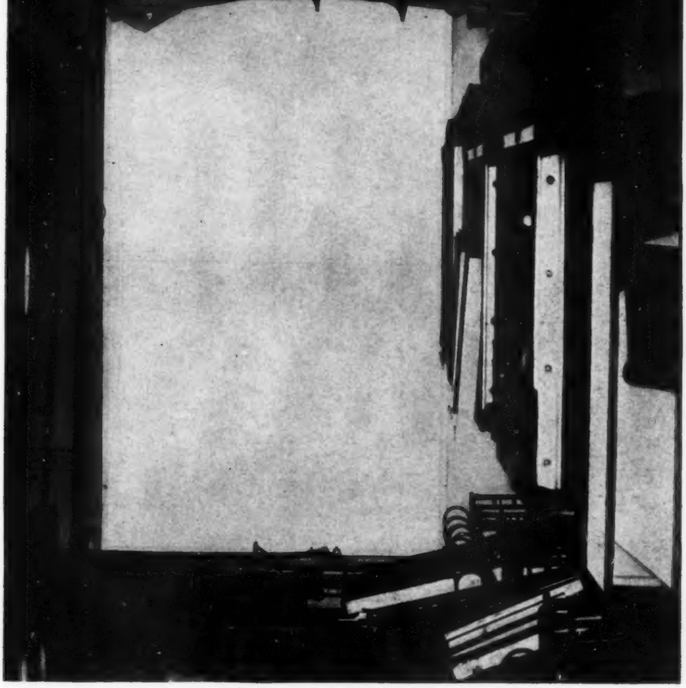


Fig. 9-b

spaces between the filament images on the shutter are filled with the reflected light (Fig. VII. B.).

This setting is very important. If the mirror image falls on the lamp filament coils instead of between them, not only is this additional light cut off from the screen, but the life of the lamp may be slightly shortened due to overheating. Whether the mirror is properly set or not may easily be observed by quickly inserting and removing any opaque screen between the lamp and the mirror, noting the effect on the image on the shutter. If desired, the focusing of the lamp and mirror may also be accomplished on the screen instead of the shutter by removing the objective lens. The appearance of the screen with or without the mirror images properly set will then be as in Fig. IX. A. and B. This method of focusing results in slightly more even distribution of light on the screen with very little decrease in average intensity. The degree of unevenness of screen illumination, when the filament is focused on the shutter is, however, not discernible to the average eye. Tests to determine the effect on total screen illumination (neglecting the question of evenness or otherwise of distribution) of having the mirror improperly set, gave the following results:

Mirror	properly located	Relative light on Screen (Lumens)	100
"	1-10″ to one side	" " " " "	88.0
"	2-10″ " " "	" " " " "	74.5
"	3-10″ " " "	" " " " "	74.0
"	4-10″ " " "	" " " " "	74.0
"	5-10″ " " "	" " " " "	74.0
"	1-10″ ahead	" " " " "	90.0
"	2-10″ "	" " " " "	81.0
"	3-10″ "	" " " " "	79.0
"	4-10″ "	" " " " "	76.0
"	5-10″ "	" " " " "	73.0
"	1-10″ above	" " " " "	84.5
"	2-10″ "	" " " " "	68.5
"	3-10″ "	" " " " "	68.0
"	4-10″ "	" " " " "	68.0
"	5-10″ "	" " " " "	68.0

A possible source of large loss is in the alignment of the condenser lens and the objective lens. It is important that the face of the condenser be parallel to the face of the projection lens, and also that the center of the two are on the same axis passing through the center of the light source and the center of the mirror. Tests were made in which the condenser was properly lined up and the screen lumens measured. The condenser was then moved to one side in steps of 1-10″ also up in steps of 1-10″. The results were as follows:

Condenser	properly centered	Relative light on Screen (Lumens)	100
"	1-10″ to one side	" " " " "	72.5
"	2-10″ " " "	" " " " "	39.5
"	3-10″ " " "	" " " " "	24.0
"	4-10″ " " "	" " " " "	20.5
"	5-10″ " " "	" " " " "	20.0

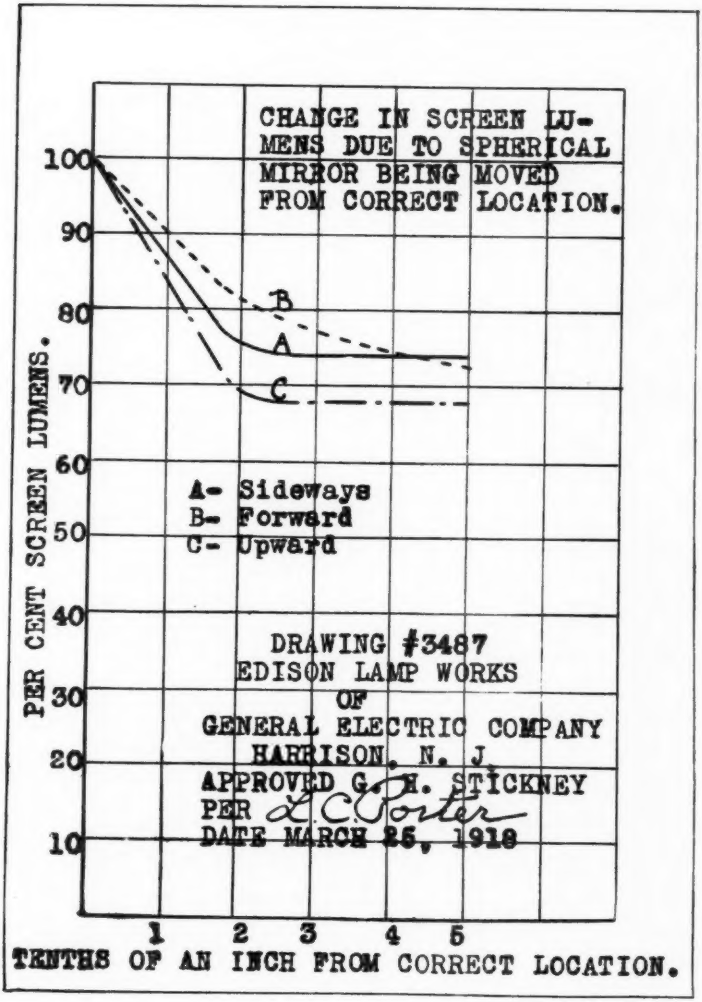

CHANGE IN SCREEN LUMENS DUE TO SPHERICAL MIRROR BEING MOVED FROM CORRECT LOCATION.
PER CENT SCREEN LUMENS.
100
90
80
70
60
50
40
30
20
10
B
A
C
A- Sideways
B- Forward
C- Upward
DRAWING #3487
EDISON LAMP WORKS
OF
GENERAL ELECTRIC COMPANY
HARRISON, N. J.
APPROVED G. H. STICKNEY
PER L. C. Porter
DATE MARCH 25, 1918
1
2
3
4
5
TENTHS OF AN INCH FROM CORRECT LOCATION.

Fig. 10

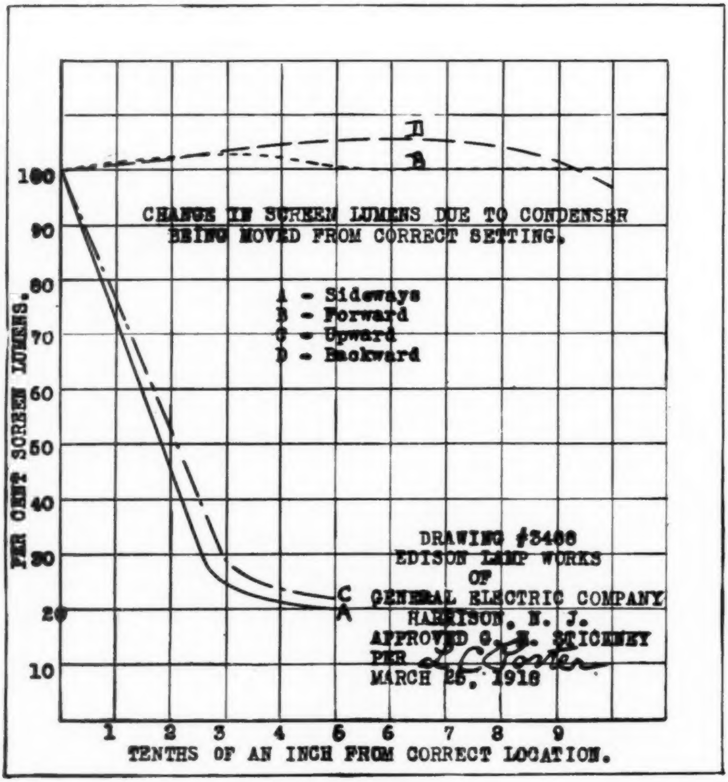

CHANGE IN SCREEN LUMENS DUE TO CONDENSER
BEING MOVED FROM CORRECT SETTING.
A - Sideways
B - Forward
C - Upward
D - Backward
D
B
C
A
100
90
80
70
60
50
40
30
20
10
PER CENT SCREEN LUMENS.
1
2
3
4
5
6
7
8
9
TENTHS OF AN INCH FROM CORRECT LOCATION.
DRAWING #3468
EDISON LAMP WORKS
OF
GENERAL ELECTRIC COMPANY
HARRISON, N. J.
APPROVED G. H. STICKNEY
PER L C Porter
MARCH 25, 1918

FIG. 11

Condenser properly centered		Relative light on Screen (Lumens)						100
"	1-10″ up	"	"	"	"		"	88.0
"	2-10″ "	"	"	"	"		"	58.5
"	3-10″ "	"	"	"	"		"	29.0
"	4-10″ "	"	"	"	"		"	22.5
"	5-10″ "	"	"	"	"		"	22.0

A slight change in the distance between the condenser and the aperture plate has little effect, though the distance should be approximately right, *i. e.*, 5″ for the 3½″ diameter condenser and 6½″ for the 4½″ diameter. Tests on the 4½″ diameter condenser showed the following variation in screen lumens obtained by moving the lens ahead of and behind its proper location:

*Condenser	6½″	from	aperture	plate	Relative	Light	on	Screen	(Lumens)	100
"	6¾″	"	"	"	"	"	"	"	"	103
"	7″	"	"	"	"	"	"	"	"	100
"	7¼″	"	"	"	"	"	"	"	"	100
"	7½″	"	"	"	"	"	"	"	"	103
"	6¼″	"	"	"	"	"	"	"	"	103
"	6″	"	"	"	"	"	"	"	"	105
"	5¾″	"	"	"	"	"	"	"	"	105
"	5½″	"	"	"	"	"	"	"	"	97

Presumably the condenser and objective lens are properly lined up at the factory and it should not be necessary to change this setting. It is well, however, to check this matter and to use great care after moving the lamp-housing sideways for lantern slide projection to get it back in the proper position before continuing the motion picture projection. There are three simple methods by which the centering of the condenser may be checked:

Let one man, provided with a piece of dark glass, place his head in the beam of light about 10 feet in front of the projector and look through the dark glass directly into the objective lens. The observer's head should be in such a position that the shadow thereof falls on the exact center of the lighted part of the motion picture screen. Looking into the objective lens through the dark glass, the corrugations on the condenser become clearly visible. An assistant should then move the condenser until these rings are concentric with and centered in the objective lens (Fig. XII. A and B.)

If one is to line up quite a number of machines, time may be saved by having a simple mechanical device made for this purpose (Fig. XIII). The device consists of a straight rod (A) pointed at each end. A section of a cone (B) of such a diameter that its center will fit snugly into the objective lens jacket after the lens tube has been removed. This cone-shaped piece also has a hole through it fitting snugly to the rod (A). A tapered rectangular piece (C) is also provided to fit snugly into the aperture plate. This piece also has a hole in it fitting rod (A) snugly. A circular plate (D) is provided with a good substantial shoulder bored to fit rod (A). These parts may be made of steel or wood, preferably steel. In using them remove the lens tube from the objective lens and insert cone (B) in the jacket. Insert rectangular

*The distance between condenser and lamp remaining fixed.

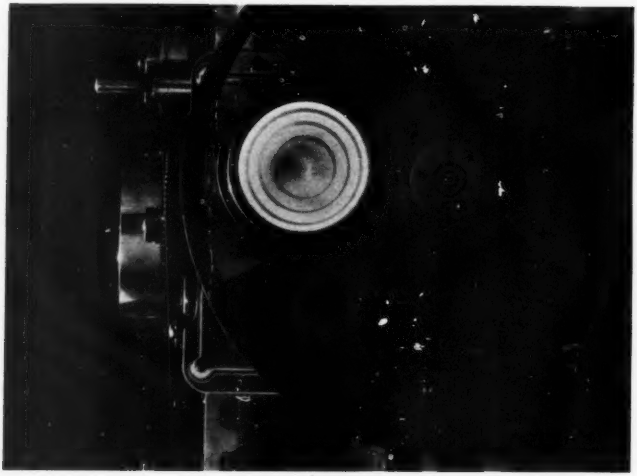


FIG. 12-A

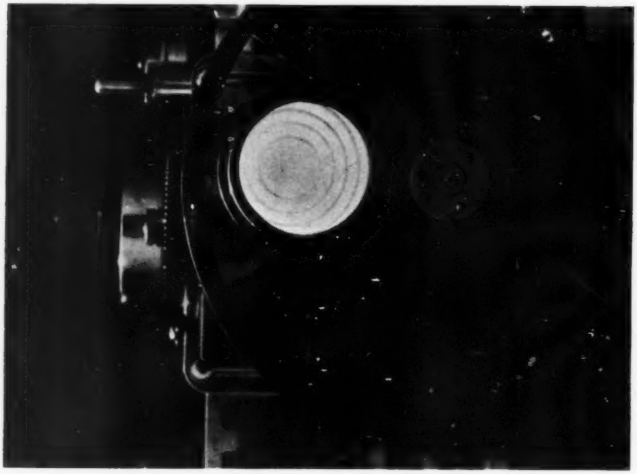


FIG. 12-B

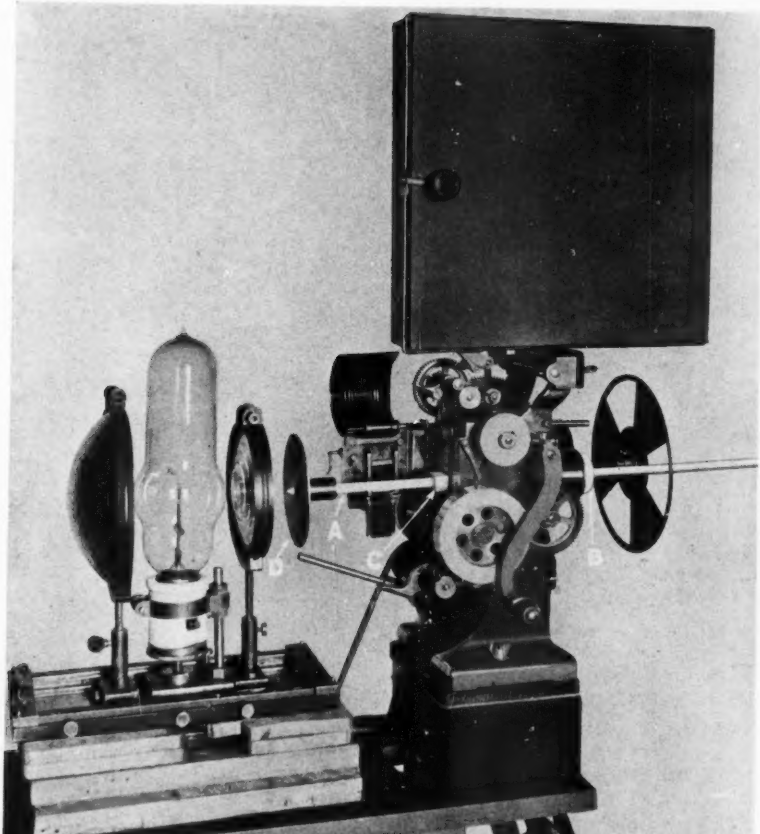


Fig. 13

block (C) in the aperture plate and pass rod (A) through them. It then becomes a simple matter to place the center of the condenser against the pointed end of the rod and thus centering it perfectly with the aperture plate and projection lens.

The plane of the condenser is made parallel to the plane of the aperture by placing disc (D) on the end of the rod and having the face of the condenser touch the disc on its entire circumference. If desired, the mirror may be similarly centered before the condenser is put in place. From the curves shown it is easy to see that if two or more of the component parts of the optical train are slightly out of line a very large loss in screen illumination may result.

The use of wide aperture projection lenses is advocated with incandescent lamps, (Fig. XIV.) The light transmission possible through 5½" focus lenses of varying diameters is approximately in the following ratio:

Focus	Diameter	Relative Transmission
5½"	1½"	36
5½"	1¾"	49
5½"	2"	64
5½"	2¼"	82
5½"	2½"	100
5½"	2¾"	121
5½"	3"	144

The use of wide aperture projection lenses results in considerably greater gain in screen illumination with the tungsten filament lamp than with the arc. In the former, the light rays emerge diverging from the lens and practically its entire aperture is effective. On the other hand, with the arc system we have crossing rays and the outer portions of the lens are not so effective as the center in transmitting the light, *i. e.*, due to the greater distance between aperture and condenser, and therefore, narrower angle of light with the arc system, a greater proportion of the light flux is passed through the central portion of the objective lens (Fig. XV.)

The color of the light from the incandescent lamp is warmer than that of the arc and generally more pleasing on that account. There are, however, a few conditions where it is desirable to imitate closely the color of the arc. Thus, in film exchanges and studios, a customer who is an arc user may want to select his films with due reference to his own illuminant. In the film studios, where the selection is made, the pictures are generally projected a relatively short distance, 25 or 30 feet, and a fairly small-sized picture shown. Under these conditions the Mazda lamp offers more than a sufficient amount of light.

We may, therefore, sacrifice a small amount in altering its color to conform closely to that of the arc. This may be accomplished by inserting between the condenser and the aperture plate a piece of glass of the proper quality. Such glass is available as a lamp bulb, *i. e.*, there are incandescent lamps manufactured for color matching purposes with bulbs made of this very special glass. They are known as Mazda C2 lamps. A good stunt is to obtain an old, burned-out 500 watt PS-40

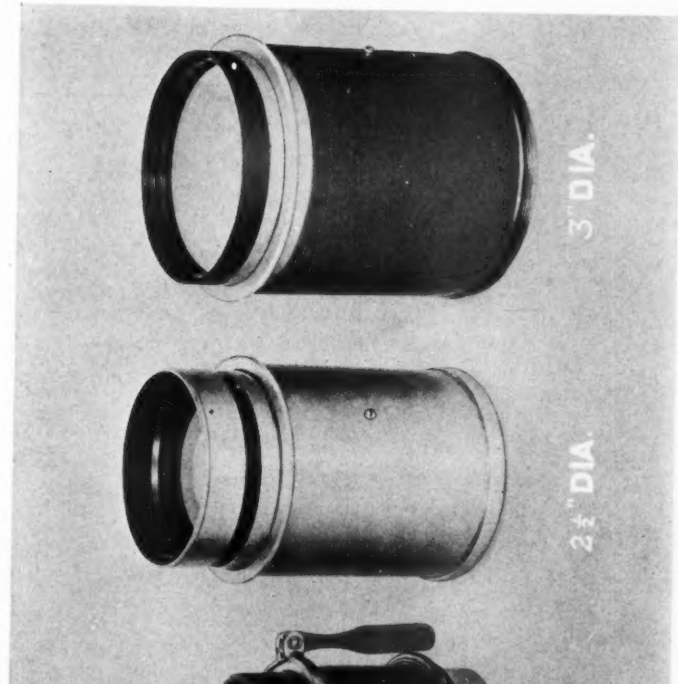


FIG. 14

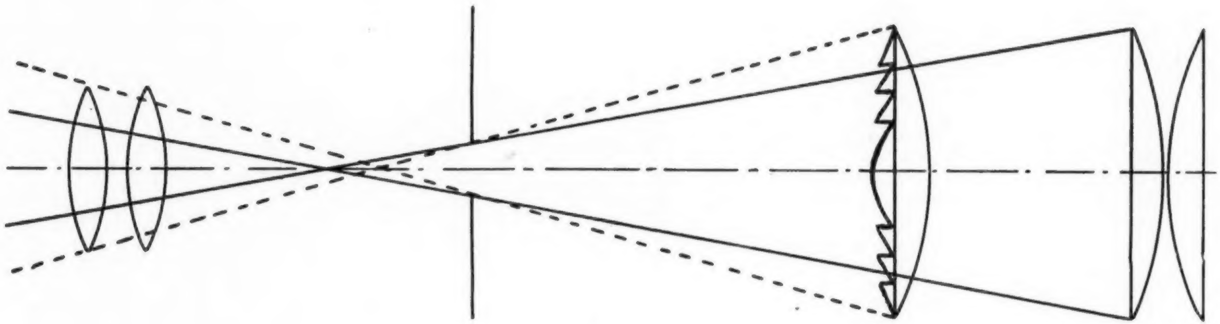


FIG. 15

bulb Mazda C2 lamp and remove a section of the bulb to place in front of the aperture of the motion picture machine. There is an old trick that may be used in removing this section of the C2 bulb. With a fine file, make a scratch on the bulb, then take a hot soldering iron, poker or any convenient pointed piece of hot metal, and place it on the filed scratch on the glass. A crack will start which will follow the hot iron wherever it is moved around the lamp bulb. In this way a nice piece of C2 glass may be easily detached from the bulb.

TESTING

Until recently it was more or less difficult to measure illumination. Photometers were expensive and considerable practice necessary to read them accurately. Now, however, there is available, at a low price, a foot candle meter which can be used to great advantage in measuring the illumination projected by various lens systems or other devices, which it is desired to compare.

In measuring screen illumination there are two methods in common use. One is to divide the actual motion picture screen into sixteen equal rectangles and measure the light intensity at the center of each of these; then average all the foot candle readings thus obtained, and multiply that average by the area (in square feet) of the screen. The result will be the total amount of light in lumens on the screen. The chief advantage of this method of measurement is that the distribution of light over the screen, *i. e.*, its relative evenness or otherwise, is measured. The disadvantage is that measuring 16 points on the screen (and for accuracy sake taking three readings at each point) is a rather lengthy process. These readings are usually taken without the film in the machine and with the rotating shutter stationary.

The total screen lumens may be obtained more quickly by placing a piece of good diffusing glass (dense opal) over the objective lens. The foot candle meter may then be mounted at any convenient, fixed distance in front of this glass and the intervening space inclosed with black cloth or paper so as to shut out all extraneous light. If many tests are to be made, it will be found convenient to build a box lined with black velvet. This box should have an opening in one and to fit snugly around the projection lens; an opening in the opposite end for the foot candle meter; and an opening at the top near the projection lens through which to view the scale of the foot candle meter. Relative emitted lumens may then be measured by one set of readings.

If it is desired to obtain actual rather than comparative values, this device should be calibrated by removing the diffusing glass and reading the 16 stations on the motion picture screen, as described above. Then read in the box with the diffusing glass in place. If, for example, it is found that there are 600 lumens on the screen and the foot candle meter in the box reads 2.00, then the constant by which the box readings should be multiplied to convert to actual lumens is 600 divided by 2 or 300.

If considerable experimental work is to be done, it will be found more convenient to use an optical bar than an actual projection machine. So far as the optical end is concerned, all of the mechanism of

Fig. 16

the machine is unnecessary. If some means is provided for holding an objective lens, an aperture plate, condensers, lamp and mirror and varying the position of each of these elements in three directions, *i. e.*, forward and back, sideways and up and down, a most convenient testing device will result. Figure XVI shows such an optical bar. In this case the bar is mounted on a see-saw effect which may also be rotated. By this means the 16 points on the motion picture screen may be measured, leaving the foot candle meter in one position and moving the lighted field around by means of the see-saw effect. This may be calibrated and degrees or any other measured amounts of tilt and rotation marked thereon for convenience in quickly obtaining the desired settings.

The field of application for motion picture machines using Mazda lamps for light sources is large. Already the art has advanced to a point where, (taking into consideration the somewhat lower results obtained under average practical operating conditions than are possible under the best conditions) incandescent motion picture lamps will successfully replace any A. C. arc on 25 cycle current, 50 ampere A. C. arcs on alternating current of 60 cycles and above, also 25 ampere D.C. arcs. In other words, 12-foot pictures projected on a plain, white screen, or 16-foot pictures on metallic or mirror screens, up to throws of 100 feet. By such a replacement better pictures are secured at a lower operating cost.

The Society of Motion Picture Engineers has, among its members, many men actively engaged in the manufacture of large as well as small or portable motion picture machines. There is a wonderful field open to these gentlemen. The educational possibilities of the motion picture machine are enormous. It is the authors' belief that some day the house machine, and those for use by salesmen, etc., will vastly outnumber its larger prototype, now so common in the motion picture theatre. The two factors which will contribute most to this accomplishment are, Safety and Simplicity. The use of the tungsten filament lamp for a light source secures the latter and contributes largely toward the former. After Simplicity and Safety we desire Excellence of screen results.

It is hoped that a careful study of the data presented above will be of assistance to you manufacturers in producing the highest grade machines, and to the users of these machines in getting the best out of them, thereby jointly obtaining excellent pictures.

The lamp manufacturers are with you from start to finish, both in the interest of science, and the advance of education, as well as from the commercial standpoint. Our various engineering departments are in a position to assist you in your developmental work, and we shall be glad to have you call for such assistance at any time.

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